MOPO013

Experimental study of beam energy control at the TIARA AVF cyclotron

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▪ Introduction

^{211}At (half-life, 7.2 h) is produced for alpha nuclear medicine therapy research using helium beam accelerated by the TIARA AVF cyclotron. The production of ^{211}At uses the nuclear reaction of ^{209}Bi(α, 2n) ^{211}At. The ^{211}At yield in this nuclear reaction increases up to about 30 MeV in the injection energy of the He beam into the Bi target. On the other hand, the nuclear reaction of ^{209}Bi(α, 3n) ^{210}At produces ^{210}At (half-life, 8.1 h) when the injection energy of the He beam into Bi surpasses 29 MeV. ^{210}At is chemically inseparable from ^{211}At, and decomposition produces ^{210}Po (half-life, 138 d), which is highly toxic. Given that ^{210}Po has a longer half-life than that of ^{211}At, this poses the problem of being left as an impurity, such as in the case of drugs manufactured for clinical use.

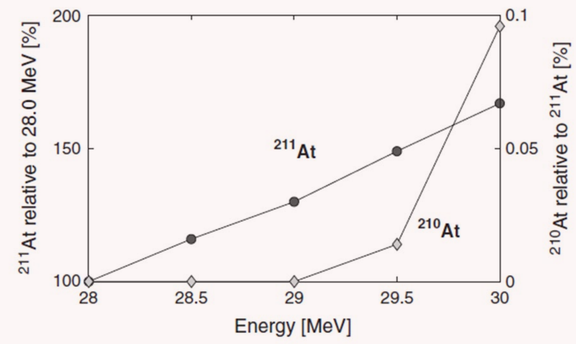

Figure 4. Relative (compared to irradiation at 28.0 MeV) ^{211}At activity along with the relative (compared to ^{211}At production) ^{210}At activity measured over the nominal energy range of 28.0 to 30.0 MeV.

J. Label Compd. Radiopharm 2012, 55 436–440

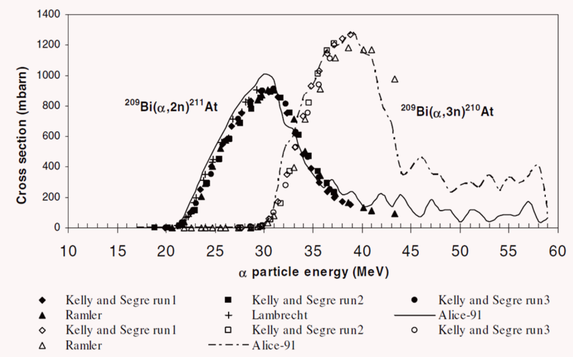

Figure 1. Experimental excitation functions of the reactions ^{209}Bi(α,2n)^{211}At and ^{209}Bi(α,3n)^{210}At reported in the literature, together with those calculated with the ALICE-91 code.

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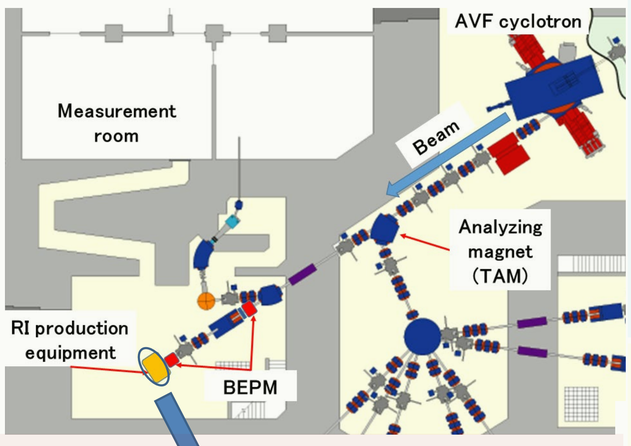
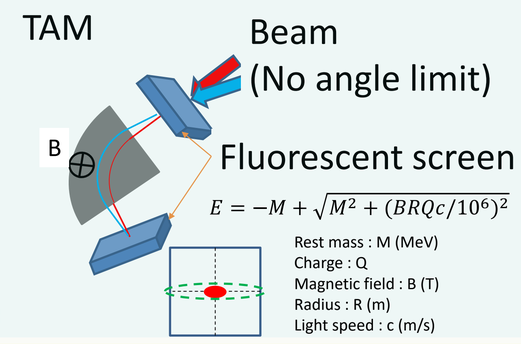
For the mass production of ^{211}At, it is necessary to increase the intensity of the incident beam and precisely control the beam energy near the upper limit, wherein ^{210}At is not generated. Therefore, in this study, we investigated the control of the beam energy in the cyclotron.

▪ Beam energy measurement

We have two beam energy measurement methods using TAM and BEPM.

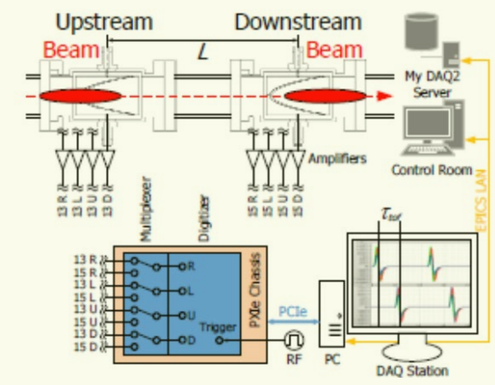


TAM



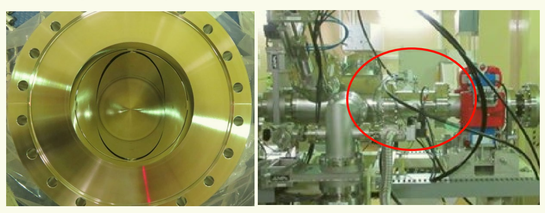
For measurements using TAM:
· Irradiation for RI production cannot be performed for more than 1 hour because of the excitation and demagnetization of the TAM, beam energy measurement, and further beam transport adjustments.
· It is not accurate because there is no beam angle limitation..

BEPM



T. Watanabe *et al.*, Proceedings of the 14th Annual Meeting of PASJ, August 1-3, 2017, Sapporo, Japan, 1114- 1117.

For measurements using BEPM (beam energy and position monitor):
· The beam energy can be measured in real-time by the time-of-flight of the beam bunch passing through the two pickup electrodes.



Bi target

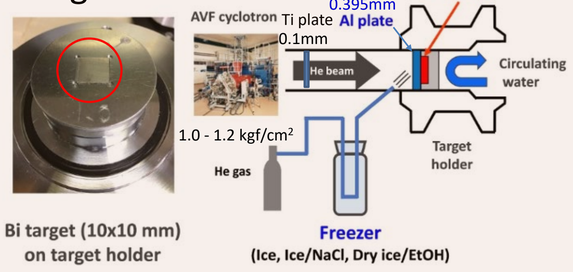


Fig. 1. Bi target (left) and target setup (right).
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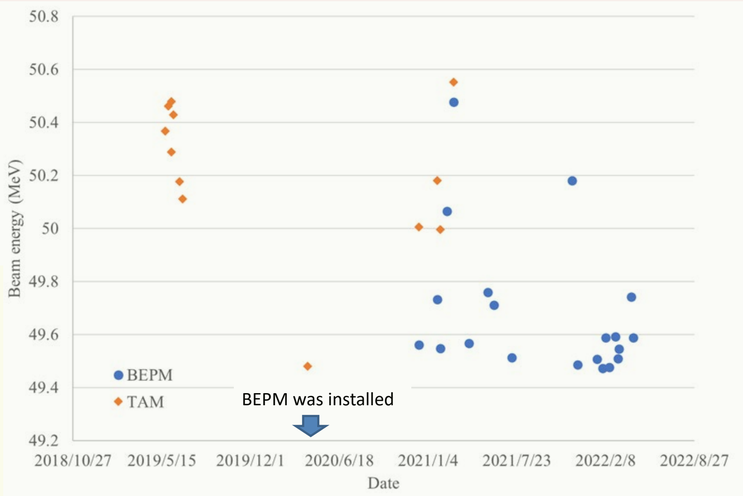
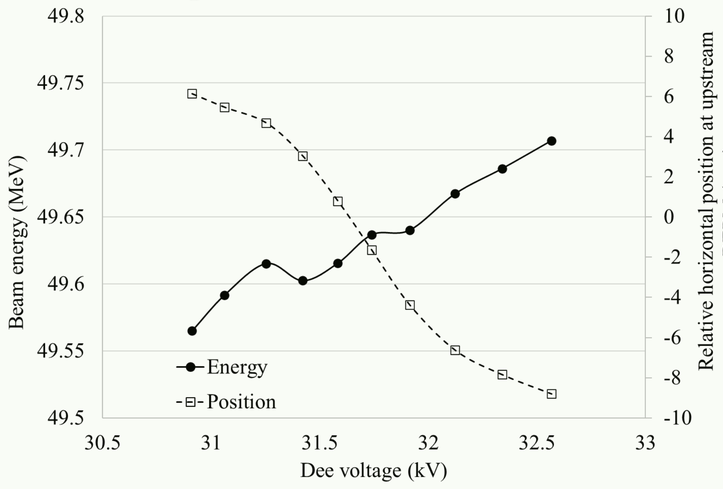
· In the TIARA, the He beam is accelerated to about 50 MeV as it must pass through the He gas used to cool the Bi in the target holder and the Ti plate separating it from the vacuum.

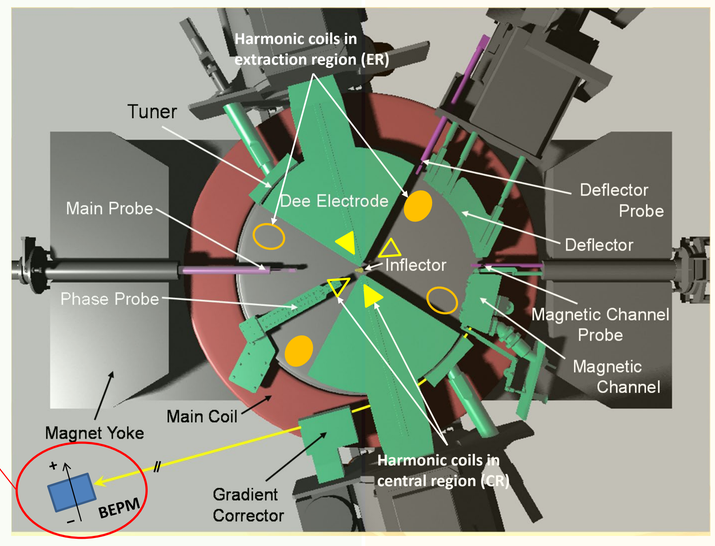


· The beam energy measured by the TAM was higher than that by the BEPM.
·The beam energy measured on each experimental day varies by about 1% or more.
· The beam energy fluctuation within the same experimental day was less than about 0.1%.

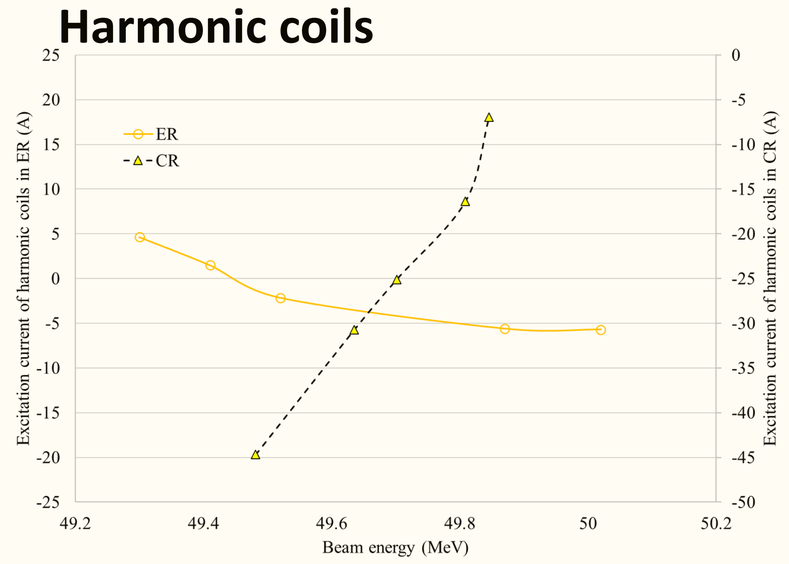
▪ Variation of beam energy with cyclotron parameters in BEPM measurements

Dee voltage





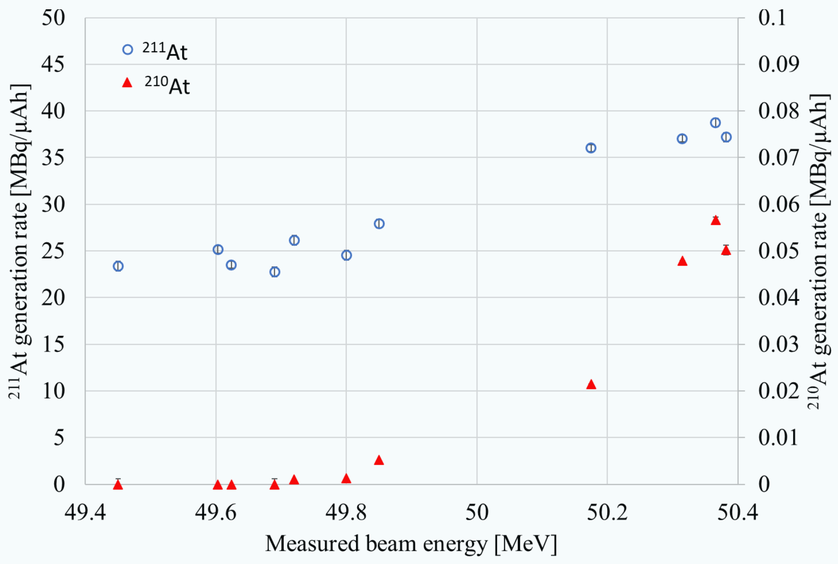
Harmonic coils



· When the Dee voltage is increased, the beam orbit in the cyclotron moves outward as the energy gain increases and the beam is deflected to the left.
· The positive position of the beam is to the right of the beam's direction of travel, while the negative direction is to the left.
· Although the Dee voltage can vary the beam energy, it is difficult to produce a large difference in beam energy by the Dee voltage alone because of the large changes in beam intensity and orbit.

· The beam energy changed by the excitation current of one set of harmonic coils in the central region (CR) and in the extraction region (ER) was measured.
· The width of the change in the excitation current of the harmonic coils in the ER was narrower and the energy variation is more sensitive than that in the CR.
· It should be noted that simple fine adjustment can change the beam energy.

▪ Generation rate of ^{211}At and ^{210}At by beam energy control



· The changes in the generation rates of ^{211}At and ^{210}At were investigated by varying the energy of the He beam injected into the Bi by the Dee voltage and excitation current of one set of harmonic coils in the CR.
· The nuclide identification and quantitative analysis from irradiated Bi were performed using a Ge semiconductor detector.
· With increasing energy, the generation rate of ^{211}At increases, while ^{210}At appears at beam energies around 49.7 MeV.
· The optimum beam energy for the production of ^{211}At in our irradiation equipment is 49.6 MeV.

▪ Conclusion

The TIARA AVF cyclotron allows precise control of the beam's energy by changing the Dee voltage and the excitation current of the harmonic coil. Changes in the beam energy due to these parameters can be measured in real-time using the BEPM. We plan to search for the optimal parameters with less variation in the extracted beam current and beam position and a wider range of beam energy changes.

▪ Acknowledgments

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