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## Use of radioactive ions in therapy

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The relativistic high-energy heavy-ion beam gives the good localized dose distribution and the large relative biological effectiveness, thus twelve heavy-ion radiotherapy (HIRT) facilities are under operation and six are under commissioning or construction worldwide. HIRT awakens worldwide interest. It is expected that clinical results will be improved through the more concentrated dose distribution on tumour with the smallest margin on normal tissues. In order to verify the real dose distribution and to obtain more accurate treatment planning, the radioactive nuclear beam (RNB) was developed. The position of implanted particles can be measured, since a short-lived positron emitted nuclei such as  $^{11}\text{C}$  or  $^{19}\text{Ne}$  can be detected its position with a positron camera or a positron emission tomography (PET).

The application of RNB was originally studied at BEVALAC of the Lawrence Berkeley Laboratory in 1980's. Although their early results showed useful data on the error of the stopping power in the treatment planning causes from the difference between the X-ray CT numbers and the actual stopping power, unfortunately, BEVALAC was shut down before the full completion of the RNB application. A  $^{12}\text{C}$  beam is used for cancer therapy at the Heavy Ion Medical Accelerator in Chiba (HIMAC) since 1994. Preclinical studies of RNB have been continued at HIMAC. The biological and chemical process of the metabolism is an important parameter for the precise measurement. The biological lifetimes in animals have been observed. An efficient detector system and an intense RNB production system have been developed too.

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