PRELIMINARY DESIGN FOR A CYCLOTRON EXTRACTION BEAM LINE AND EXTERNAL TARGET FOR PRODUCING GALLIUM-68 & TECHNETIUM-99M ISOTOPES: A DEVELOPING COUNTRIES SCENARIO

L.F. SALAS-TAPIA & T. ZHANG,
Harbin Engineering University, Harbin, China

L.F. ECHEVERRI-ECHEVERRI
Universidad del Cauca, Popayán, Colombia

Currently, over 1500 cyclotrons around the world are being used for isotope production [1]. From that amount, more than a half of those machines have particle exiting energies below 20 MeV. These low and medium energy range cyclotrons are mainly located in developing countries. Cyclotron-based solutions for developing countries can contribute in some extent to foster the accessibility of radiopharmaceuticals to more human beings requiring these substances [2]. When analyzing the figures [1], low to medium energy machines are mainly designed to hold an internal target for their irradiation routines. However, this kind of configuration does not allow to test and analyze easily new targets for producing a wide variety of radioisotopes commonly used in the medical and industrial environment. Moreover, cyclotrons with internal targets are more susceptible to undergo periodic maintenance procedures leading to a lost of pressure in the main Dees cavities [3].

Nowadays Technetium-99m (Tc-99m) represents the most used nuclear medicine isotope around the globe [4]. Many daily procedures rely on its physical properties to offer a diagnostic service for patients inside health care facilities. In the same way, recently Gallium-68 (Ga-68) has contributed in the advancing of the PET-CT technique due to its proper half-life time and ability to form new ligands [5]. These two previous isotopes can indeed be produced in low to medium energy cyclotrons. This is due to the energy range of these machines belongs to the nucleon cross section for both Tc-99m and Ga-68 when bombarding a target with protons [6][7]. Achieving a practical way to produce both Ga-68 & Tc-99m using an accelerator-based approach could decrease the high dependency on both ${}^{68}_{32}Ge/{}^{68}_{31}Ga$ & ${}^{99}_{42}Mo/{}^{99m}_{43}Tc$ generators [8].

In this work, a preliminary design of the external beam line for a general small and medium-sized cyclotron is designed using theoretical accelerator physics concepts and computational tools & codes. Using an extraction beam line will also allow us to have a better understanding on the proton beam shape—useful for the production yield calculations. The H^- ions that were accelerated inside the cyclotron are stripped off in order to get protons. As from the cyclotron the exiting energy of the protons considered here is around 17 MeV, the main idea of the beam line is to hold this energy across the linear trajectory till the particles reach the target—the calculated length of the beam line is supposed to be from one to two meters. This beam line behaves, in some extent, as a proton linear accelerator. When particles are impacting the external target main structure for producing our desirable isotopes (Tc-99m & Ga-68), many secondary particles are created such as neutrons and photons. Thus, in this work we also considered the required shielding for protecting the surroundings of the machine from ionizing radiation. The target whole structure which fits into the beam line is supposed to be self-shielded, therefore a practical design is proposed in this investigation with the objective of containing hazardous radiation as much as possible. Regarding the isotope production yield, two generic external targets are designed which incorporate the proper integrated energy degrader thickness for achieving the adequate nucleon cross section for two particular reactions of interest using a solid target: ${}^{68}_{30}Zn(p,n){}^{68}_{31}Ga$ & ${}^{100}_{42}Mo(p,2n){}^{99m}_{43}Tc$.

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