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RESEARCH ARTICLE

HYBRID MACHINES PET/CT SCANNERS BY USING ^{18}F, ^{82}SR AND ^{68}GE RADIONUCLIDE

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ABSTRACT

The increased use of hybrid PET /CT scanners combining detailed anatomical information along with functional data has benefits for both diagnostic and therapeutic purposes. This presented study is to make comparison of cross sections to produce ^{18}F , ^{82}Sr and^{68}Ge via different reactions with particle incident energy up to 60 MeV as a part of systematic studies on particle-induced activations on enriched ^{nat}Ne, ^{nat}Rb, ^{nat}Ga ^{18}O,^{85}Rb, and ^{69}Ga targets, theoretical calculation of production yield, calculation of required target and suggestion of optimum reaction to produce: Fluorine-18 , Strontium-82 andGermanium-68 to use in Hybrid Machines PET/CT Scanners.

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INTRODUCTION

Since the first prototypes over a decade ago, the continued use of PET/CT in the clinic has introduced ever increasing applications as clinics gain more experience and realize the potential. The ability to combine detailed anatomy with function has even spurred another technology breakthrough. This review covers numerous aspects of combined PET/CT; from quality assurance and imaging artifacts to diagnostic and therapeutic uses [1].

The goal of the PET/CT prototype was to overcome some of the technical and logistic difficulties associated with the software approaches by acquiring both clinical-quality anatomic images and clinical-quality functional images in a single scanning session ,that such a device will encourage involvement in molecular imaging of other medical specialists such as radiologists, surgeons, and oncologists specialists who are more familiar with high-resolution anatomic imaging than with the tracer techniques of functional imaging. Combined PET/CT.

Principles and Application

PET/CT scanners usually have a large bore size (70 cm diameter; 100 cm axial length) allowing for the use of immobilization devices and larger patients1. The CT scanner is usually in the front of the gantry and may be acquired in axial or helical mode. The PET scanner is usually located in the back of the gantry and may be acquired using two or three dimensional modes.

This hybrid unit consists of two separate devices, namely a PET and a CT scanner, linked by one common bed and workstation console where data from both modalities are acquired sequentially rather than simultaneously as planned during the earlier conceptual design of the machine [2]. Commercial PET/CT systems are usually configured by designing a gantry that mounts a stationary PET detector ring in tandem with a platform that rotates the CT imaging chain around the patient using a mechanical configuration similar to that used in a conventional diagnostic CT scanner Performing PET and CT measurements within the same system without moving the patient relative to the table make the registration problem easier.

PET when combined with CT imaging gives the greatest information as far as delineating tumor extent for many types of cancers. This allows for precise targeting of the tumor using radiotherapy. Typically beams are confined to treat the gross tumor volume along with a margin which supposedly encompasses microscopic disease [3].

However, there are no strict guidelines as to how much of a margin to include. This is important because the larger volume of tissue of which is irradiated, the greater chance of normal tissue complications. If the exact extent of the tumor spread were known, then the absorbed dose could be increased at the tumor location while modulating the beam to minimize dose elsewhere, the addition of PET imaging to CT also allows for

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the possibility of dose painting. For example ^{18}F-FDG PET may be used to locate the more active regions of a tumor as determined by glucose consumption. Zhou *et al*. used ^{18}F-FDG PET activity as a surrogate for tumor cell density for biological dose calculations [4, 5].

Modern PET/CT scanners are equipped with helical CT technology allowing to acquire high resolution anatomical images within a few seconds following patient positioning and definition of the axial field of view on the tow program It is therefore obvious that PET is the limiting factor when it comes to scanning speed on combined PET/CT [6].

Advantage

One main advantage of a PET/CT scanner is that it uses the CT images (as transmission images) for attenuation correction of the PET data, rather than relying on a rotating transmission rod source. PET/CT scanners are able to perform the registration of the transmission images in extremely short times (less than a minute), with the PET study acquisitions performed immediately after. Upon reconstruction, both the PET images and the CT images are displayed side by side and overlaid.

Use of the CT scan reduces the total PET acquisition time, which translates into increased patient comfort and cooperation. The availability of high-quality transmission images also leads to a more precise localization and interpretation of the hyper metabolic disease areas. While other indications benefit from PET/CT scans, today's oncology procedures far outnumber all other clinical indications

METHOD

Nuclear data play a very important role in the choice of a radioisotope for a medical application. Nuclear structure and the decay data determine the suitability of a radioisotope for diagnostic application while the nuclear reaction data study the possibility of its production in a pure form.

The feasibility of the production of ^{18}F, ^{82}Sr and ^{68}Ge via various nuclear reactions was investigated. Excitation functions of ^{18}F , ^{82}Sr and ^{68}Ge production by the reactions of ^{nat}Ne +d and ^{18}O +p to produce ^{18}F , ^{85}Rb + p and , ^{nat}Rb+ p to produce ^{82}Sr and ^{69}Ga + p, ^{nat}Ga + p to produce ^{68}Ge .

We calculated using the available data in the international libraries. According to SRIM code [7], the thick target integral yields were deduced using the calculated evaluated cross sections. A Matlab sub programs was used to solve the following yield equation (1) [8]:

$$Y=N\ P\ \sigma\ (E).10^{-30}(1-e^{-\lambda t})\ldots\ldots\ldots\ldots\ (1)$$

Whereas, σ (E) (mb) :is the average cross section at a specific energy (E); N is the number of target atoms/cm^2, λ is the decay constant of the produced isotopes, P is the number of incident protons/sec for (1 μA) and t is the irradiation time (t= 1 h). The integral target yield Y is calculated by summing up the differential yields.

RESULTS AND DISCUSSIONS

Calculation of excitation function

Production of ^{18}F

a-^{nat}Ne(d,x)^{18}F reaction

The excitation functions of the deuteron induced reaction on ^{nat}Ne were determined by equation(1) and SRIM code; (Figure.1and Figure.2). The evaluation of the results of the calculations showed that the best range of energy that favors the reaction is from(0 to 20) MeV. According to A.N. Dovbnya *et al*[9]and S.Takacs *et al*. [10], this reaction appears to be modest for the purpose of ^{18}F production.

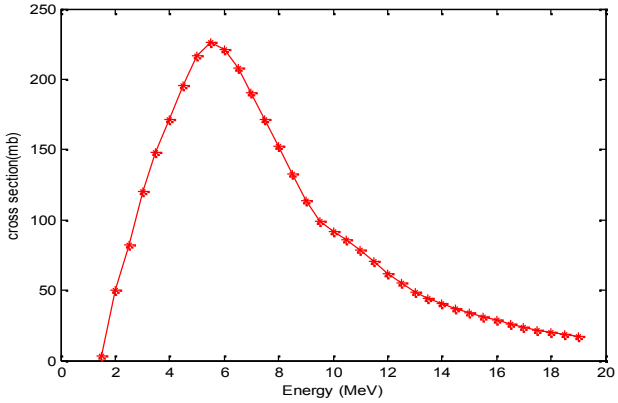

Figure1 cross sections for^{nat}Ne(d,x)^{18}F reaction

b- ^{18}O(p,n)^{18}F reaction

The ^{18}O(p,n)^{18}F reaction is an important proton incident particle for producing ^{18}F from enriched ^{18}O targets. Several authors :[11, 12 -19], studied the energy range of proton energy producing ^{18}F from 2.5 to 16 MeV ,the cross-section is obtained figure(3).

The theoretical thick-target yield using SRIM using eq.(1) is found to be equal to 1346 GBq/C as shown in figure (2). This reaction appears to be very good for the purpose of ^{18}F production to use in PET/CT[20].

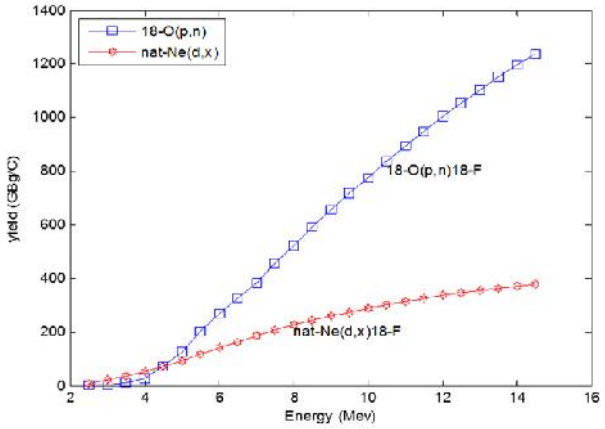

Figure 2 The excitation functions for ^{18}F of the ^{nat}Ne(d,x) and the^{18}O(p,n)^{18}F reactions

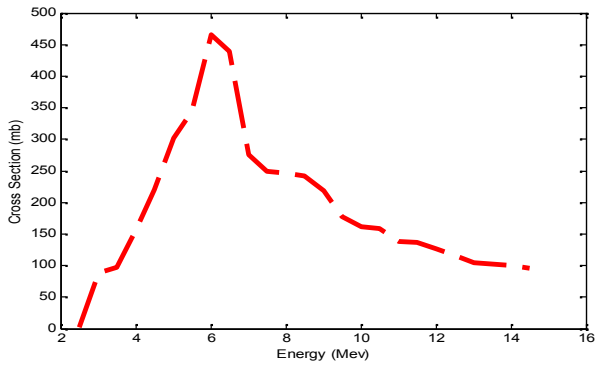

Figure3 cross sections for $^{18}O(p,n)^{18}F$

production of ^{82}Sr

a- $^{85}Rb(p,4n)^{82}Sr$ reaction

The excitation functions of the proton induced reaction on ^{85}Rb was determined by equation(1) and SRIM code (Figure. 4 and Figure.5). The evaluation of the results of the calculations showed that the best range of energy that favors the reaction is from(34 to 60) MeV. According to T.Horiguchi *et al*[21]; S.Takacs *et al* [22] and S.Kastleiner *et al* [23] . Reaction appears to be modest for the purpose of ^{82}Sr production.

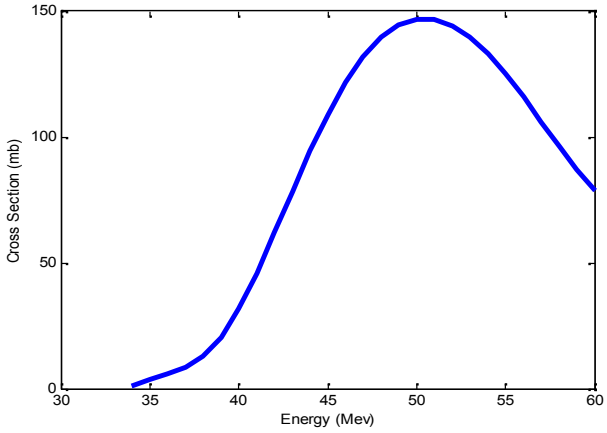

Figure 4 cross sections for $^{85}Rb(p,4n)^{82}Sr$

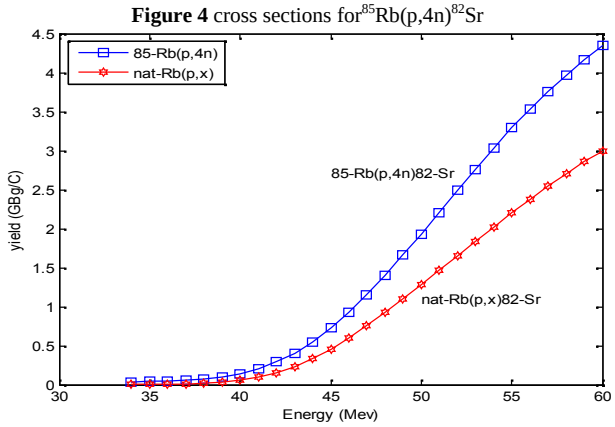

Figure 5 The excitation functions for ^{82}Sr of the $^{85}Rb(p,4n)$ and the $^{nat}Rb(p,x)^{82}Sr$ reactions

b-$^{nat}Rb(p,x)^{82}Sr$ reaction

The $^{nat}Rb(p,x)^{82}Sr$ reaction is an important proton incident particle for producing ^{82}Sr from enriched natural ^{nat}Rb targets . Several authors [24,25-30], studied the energy range of proton energy producing ^{82}Sr from 34 to 60 MeV ,the cross-section is obtained as shown in figure (6). The theoretical thick-target yield using SRIM and eq.(1) is found to be equal to 3 GBq/C as shown in figure (5). This reaction appears to be useful for the purpose of ^{1882}Sr production to use in PET/CT[4,31].

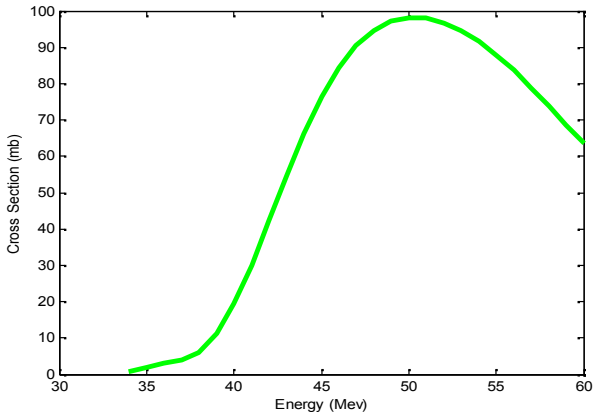

Figure6 cross sections for natRb(p,x)82Sr

production of ^{68}Ge

a- $^{69}Ga(p,2n)^{68}Ge$ reaction

$^{69}Ga(p,2n)^{68}Ge$ reaction is beneficial energy range of proton energy producing ^{68}Ge from a ^{69}Ga target is from 12 to 30 MeV ,the maximum cross-section obtained according to V.N.Levkovskij [32], S.Takacs *et al*[33] and N.T.PORILE *et al*[34] is obtained. The production yield of ^{68}Ge using SRIM code and equation(1) in the chosen energy range is 682.79GBq/C as shown in figures (7 and 8). This reaction appears to be good for the purpose of ^{68}Ge production .

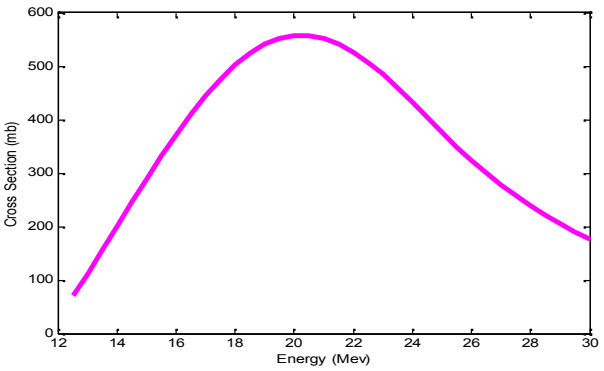

Figure7 cross sections for $^{69}Ga(p,2n)^{68}Ge$

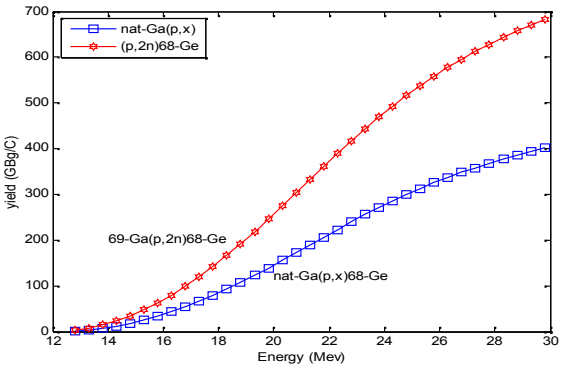

Figure8 The excitation functions for ^{68}Ge of the $^{69}Ga(p,2n)^{68}Ge$,and for $^{nat}Ga(p,x)^{68}Ge$

b- $^{nat}Ga(p,x)^{68}Ge$ reaction

$^{nat}Ga(p,x)^{68}Ge$ reaction is beneficial energy range of proton energy producing ^{68}Ge from a ^{nat}Ga target, is from 12 to 30 MeV ,the maximum cross-section obtained according to V.N.Levkovskij [32], S.Takacs *et al*[33] and N.T.PORILE *et al*[34] is obtained, the production yield of ^{68}Ge using SRIM code and equation(1) in the chosen energy range is 402GBq/C as shown in figure (8,9). This reaction appears to be modest for the purpose of ^{68}Ge production.

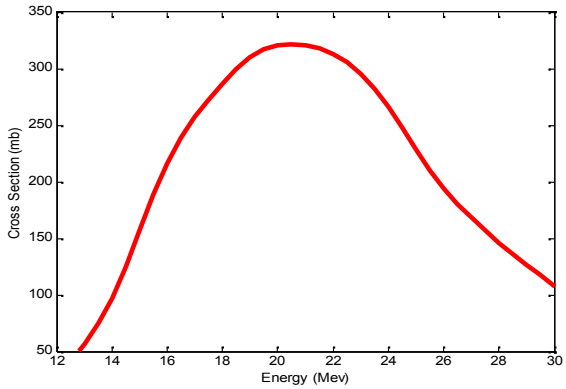

Figure9 cross sections for $^{nat}Ga(p,x)^{68}Ge$

CONCLUSIONS

The only other obstacle to the wider use of PET-CT is the difficulty and cost of producing and transporting the radiopharmaceuticals used for PET imaging, which are usually extremely short-lived . For instance, the half life of radioactive fluorine-18 used to trace glucose metabolism (using fluorodeoxyglucose, FDG) is 109.77min. only, But the use of other isotopes such as Strontium-82 (the half life=25.36 days), or Germanium-68(half life=270 days); provides the longest for the Scanners.

There are several ways to produce those isotope. The production of ^{18}F can be obtained using different nuclear reactions ,for low proton energies (0 to 16)MeV the reaction $^{18}O(p,n)^{18}F$ reaction gives best yield (1346 GBq/C)(Fig.2) ,while for the other possible reactions as the ^{nat}Ne which occurs in an energy range (0 to 20) MeV, the possible yields is in the order of (380GBq/ C) (Fig. 2).
The reaction$^{85}Rb(p,4n)$ reaction is good method to produce ^{82}Sr (4.3GBq/ C) (Fig. 5).The protron reactions play an important role to produce ^{68}Ge in $^{69}Ga(p,2n)$, with energies(12 to 30) the yield of its about (682.79GBq/C) (Fig.8).

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