RESEARCH PAPER

0.1 and 0.2 mm thin sheet of Zinc (Zn-30) used as a physical filter in Tc-99m SPECT imaging, may results to reduce scatter components.

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Abstract:

The proposed work is concerned with designing of Zinc (Zn-30) material based physical filters of different thickness, to utilize in most of Tc-99m SPECT imaging to compensate scatter events, generally described as SPECT inherent drawback. As currently available SPECT conducting systems (scintillation cameras) usually involves to use sodium iodide activated thallium NaI(Tl) crystal detectors, which has poor energy resolution as compare to other sort of crystal detectors. Due to poor energy resolution of currently engaged crystal detectors almost all SPECT examinations results unreliable, due to inclusion of scatter component in SPECT data acquisition. The standard method for data collection is to set an energy window 20% at FWHM over primary photopeak energy spectrum of radionuclide in use, but due to poor energy resolution of currently available detecting system still a significant amount 30% to 40% of scatter gamma photons are registered in primary photopeak of energy spectrum, which contaminate the whole acquired data and produce less quality and contrast SPECT Images, also represents less concentration of radiation flux density, which may result to increase or decrease counting statistics. The overall situation compromises SPECT frequent utility in clinical procedures. Proposed work seems to have potential influence to reduce some fraction of scattering by means of attenuating low energetic (scatter) gamma photons, prior to reach the detecting surface of crystal detectors, hence enhance the quality and contrast of SPECT perceived images and SPECT quantification, by means of eliminating scatter gamma photons from SPECT data acquisition.

01. Introduction

Single Photon Emission Computed Tomography (SPECT), is diagnostic modality of nuclear medicine technology, mostly used to render two dimensional (2-D) or three dimensional (3-D) representation of human tissue or organ, for diagnosis and treatment management procedures. SPECT seems to have great potential, and playing vital role, as one of the best imaging modality in human health. Information extracted from SPECT procedures is an important source for therapeutic management. Every year millions of people / patients undergo SPECT investigations worldwide. SPECT provides functional or anatomic information of human tissue, organ or body, by administering some amount of gamma emitting radionuclide into the patient body. Along with great advantageous applications, SPECT still sustain some losses, resulting to its limitations, e.g. poor energy resolution, collimator related problems such as sensitivity, scattering and absorption of gamma photons within detector material or in patient body, irregular pattern of radioactive decay and less counting statistics due to radiation dose limits or restriction [1-2]. Overall these limitations compromises its utility in clinical practice. The image quality is hampered and quantification accuracy of radiopharmaceuticals uptake is limited. The inclusion of scatter gamma photons in SPECT data acquisition is one of the most major problem among others. The standard imaging technique applies an energy window over primary photopeak of the energy spectrum of radiopharmaceuticals in use, but because of poor energy resolution a significant fraction of scattered gamma photons or registered in primary photopeak energy spectrum, and detected by crystal detectors. The inclusion of scattered gamma photons in projection data affects the actual quantification, primarily reduce the contrast or quality, also resulting the degradation of spatial resolution furthermore [3-4], so for that, to yield better SPECT results scatter correction is important because it may results to improve image quality [5]. To minimize scattering effects in SPECT data acquisition, various techniques, tools or methods have been developed by different groups of researchers, such as system based mathematical models or algorithms and implementing single, dual or multiple energy window technique to compensate scattering, however none has attend acceptability for the use in clinical SPECT as gold standard. The aim of this study is to reduce the effect of scatter gamma photons from the raw projection data with a new scatter reduction method (material or physical filter), the ultimate objective of the study is to enhance the region delectability, improve the image contrast of radiopharmaceuticals distribution. Therefore in this study, emphases is given on to tackle scatter problem only. The use of physical filter to reduce scattering in SPECT data acquisition was reported in literature.

In 2007 Syed Ayaz Ali Shah [6], reported that 0.4mm copper filter yields betterment in Standard Deviation (STD) and Signal-to-Noise Ratio (SNR) of SPECT studies. Nazifah et al [7] reported the use of 0.198 mm Zinc flat sheet as material or physical filter results in the improvement of system spatial resolution. In 2014 A. Nazifah at al [8] utilizes the material filter in SPECT, and claimed the decline of count rate from Compton and photopeak region of Tc-99m spectrum. Inayatullah Shah Sayed and Zawari Harun [9] are concluded that with the use of copper material filter technique, the image uniformity, hot region delectability and contrast are simultaneously increased. Material filter technique reduces the influence of scatter gamma photons in the projection data by means of producing good quality images were also pointed out by Inayatullah Shah Sayed and Fong Shuyee [10]. Keeping in a view above all facts and figures regarding use of physical filter in SPECT data acquisition, is to minimize the scattering, the present work is concerned with designing and analysis of Zinc (Zn-30) made physical filter of different thickness, which may use or utilize in Tc-99m SPECT imaging to reduce scatter components.

02. Material Analysis

2.1 Selection of Material to Design Physical Filter

To check possible or feasible usefulness of material for filter designing, one must account characteristic properties of material and traversing radiation, like as linear attenuation coefficient, density, atomic (Z) number and specific energy of incident radiation or photon. The percent attenuation coefficient may must be calculated by standard attenuation and transmission equation as under:

$$I = I_o e^{-ut}$$

or

$$I/Io \quad = e^{-ut}$$

Where

'I' is transmitted intensity or energy of gamma ray photons after passing throng thickness't'.

'Io' is original intensity or energy of gamma ray photons.

'µ' is linear attenuation coefficient. and,

't' is thickness of absorbing or attenuating medium.

Whereas the linear attenuation coefficient can be derived from mass attenuation coefficient with relation as under:

$$\mu_{(mass)} = \quad \mu_{(linear)} / \text{Density}$$

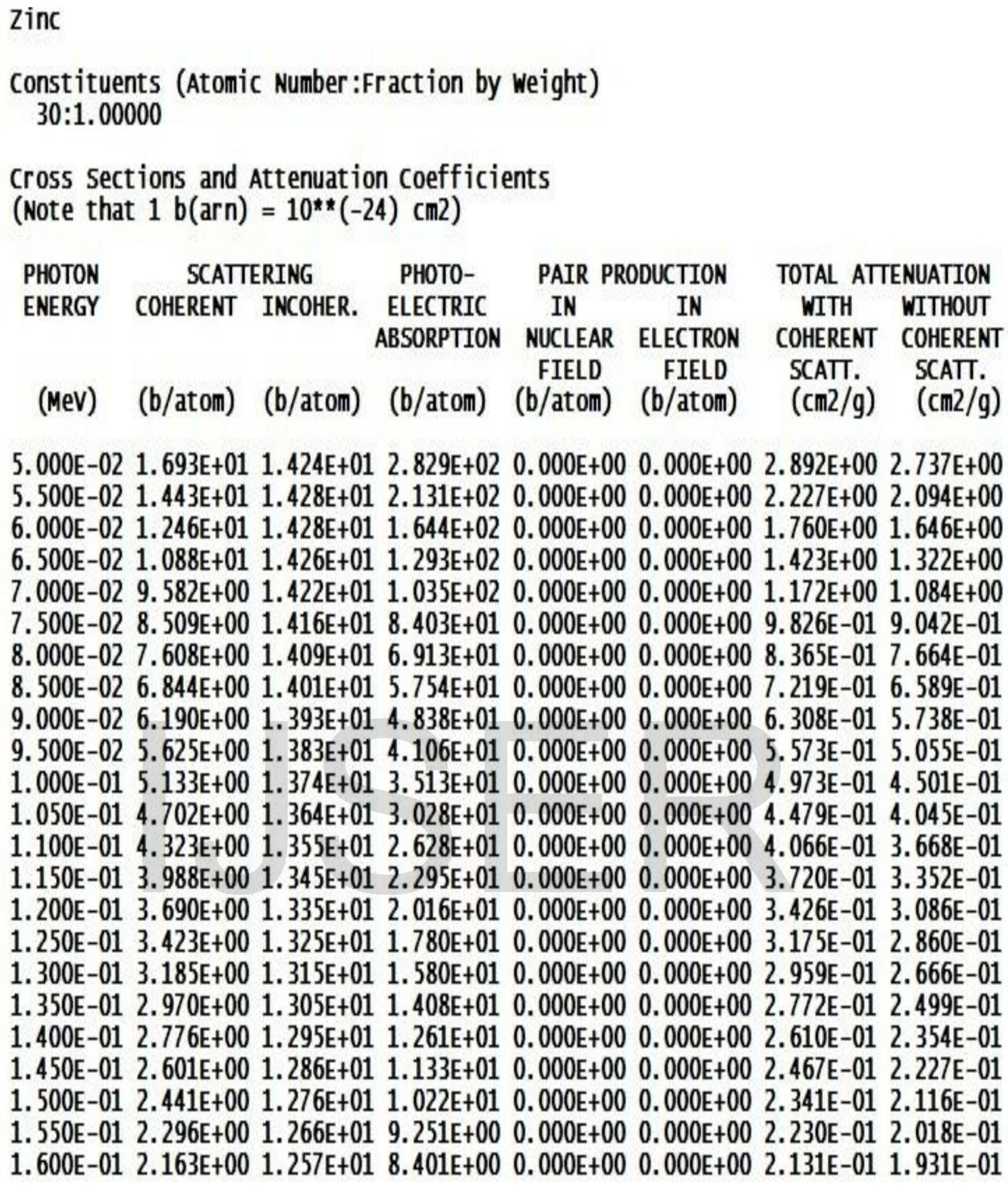
or

$$\mu_{(\text{linear})} = \mu_{(\text{mass})} \times \text{Density}$$

The data for total mass attenuation coefficient at various energy ranges of gamma photons, through selected element or compound of specific thickness were extracted from XCOM Photon Cross-Section database, generated by National Institute of Standards Technology (NIST), and operated on personal computer. The material in use was analyzed at 0.1 and 0.2 mm thickness, within energy ranges of 50 keV to 160 keV at difference of 5 keV, with and without coherent scattering.

Table 1

Showing total mass attenuation coefficient at various gamma ray energies, through Zinc



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Zinc

Constituents (Atomic Number:Fraction by Weight)
  30:1.00000

Cross Sections and Attenuation Coefficients
(Note that 1 b(arn) = 10**(-24) cm2)

 PHOTON      SCATTERING       PHOTO-     PAIR PRODUCTION     TOTAL ATTENUATION
 ENERGY   COHERENT  INCOHER.  ELECTRIC    IN         IN        WITH     WITHOUT
                             ABSORPTION NUCLEAR  ELECTRON   COHERENT  COHERENT
                                          FIELD      FIELD     SCATT.    SCATT.
  (MeV)   (b/atom)  (b/atom)  (b/atom)  (b/atom)  (b/atom)    (cm2/g)   (cm2/g)

5.000E-02 1.693E+01 1.424E+01 2.829E+02 0.000E+00 0.000E+00 2.892E+00 2.737E+00
5.500E-02 1.443E+01 1.428E+01 2.131E+02 0.000E+00 0.000E+00 2.227E+00 2.094E+00
6.000E-02 1.246E+01 1.428E+01 1.644E+02 0.000E+00 0.000E+00 1.760E+00 1.646E+00
6.500E-02 1.088E+01 1.426E+01 1.293E+02 0.000E+00 0.000E+00 1.423E+00 1.322E+00
7.000E-02 9.582E+00 1.422E+01 1.035E+02 0.000E+00 0.000E+00 1.172E+00 1.084E+00
7.500E-02 8.509E+00 1.416E+01 8.403E+01 0.000E+00 0.000E+00 9.826E-01 9.042E-01
8.000E-02 7.608E+00 1.409E+01 6.913E+01 0.000E+00 0.000E+00 8.365E-01 7.664E-01
8.500E-02 6.844E+00 1.401E+01 5.754E+01 0.000E+00 0.000E+00 7.219E-01 6.589E-01
9.000E-02 6.190E+00 1.393E+01 4.838E+01 0.000E+00 0.000E+00 6.308E-01 5.738E-01
9.500E-02 5.625E+00 1.383E+01 4.106E+01 0.000E+00 0.000E+00 5.573E-01 5.055E-01
1.000E-01 5.133E+00 1.374E+01 3.513E+01 0.000E+00 0.000E+00 4.973E-01 4.501E-01
1.050E-01 4.702E+00 1.364E+01 3.028E+01 0.000E+00 0.000E+00 4.479E-01 4.045E-01
1.100E-01 4.323E+00 1.355E+01 2.628E+01 0.000E+00 0.000E+00 4.066E-01 3.668E-01
1.150E-01 3.988E+00 1.345E+01 2.295E+01 0.000E+00 0.000E+00 3.720E-01 3.352E-01
1.200E-01 3.690E+00 1.335E+01 2.016E+01 0.000E+00 0.000E+00 3.426E-01 3.086E-01
1.250E-01 3.423E+00 1.325E+01 1.780E+01 0.000E+00 0.000E+00 3.175E-01 2.860E-01
1.300E-01 3.185E+00 1.315E+01 1.580E+01 0.000E+00 0.000E+00 2.959E-01 2.666E-01
1.350E-01 2.970E+00 1.305E+01 1.408E+01 0.000E+00 0.000E+00 2.772E-01 2.499E-01
1.400E-01 2.776E+00 1.295E+01 1.261E+01 0.000E+00 0.000E+00 2.610E-01 2.354E-01
1.450E-01 2.601E+00 1.286E+01 1.133E+01 0.000E+00 0.000E+00 2.467E-01 2.227E-01
1.500E-01 2.441E+00 1.276E+01 1.022E+01 0.000E+00 0.000E+00 2.341E-01 2.116E-01
1.550E-01 2.296E+00 1.266E+01 9.251E+00 0.000E+00 0.000E+00 2.230E-01 2.018E-01
1.600E-01 2.163E+00 1.257E+01 8.401E+00 0.000E+00 0.000E+00 2.131E-01 1.931E-01
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The data were extracted from XCOM photon cross-section database generated by National Institute of Standards Technology (NIST). [11]

Table 2
0.1mm thin sheet of Zinc (Zn-30) showing transmission and percent attenuation at various energy ranges of gamma photons with coherent scattering.

S..No.	Energy		Total mass attenuation coeff.		Density		Total Linear attenuation coefficient per mm	Thickness mm		Transmission		Percent attenuation
	MeV	keV	Mev	keV	Gram per cm cube	Miligram per mm cube		T mm	Mass thickness (Physical density multiplied by thickness)	Fraction	Percent	
1	**0.05**	**50**	2.892E+00	2.89	7.133	0.7133	2.06	0.1	0.07133	43.16	86.32	13.68
2	**0.055**	**55**	2.227E+00	2.22	7.133	0.7133	1.58	0.1	0.07133	49.13	89.32	10.68
3	**0.06**	**60**	1.760E+00	1.76	7.133	0.7133	1.25	0.1	0.07133	54.88	91.46	8.54
4	**0.065**	**65**	1.423E+00	1.42	7.133	0.7133	1.01	0.1	0.07133	60.48	93.04	6.96
5	**0.07**	**70**	1.172E+00	1.17	7.133	0.7133	0.83	0.1	0.07133	65.97	94.24	5.76
6	**0.075**	**75**	9.826-01	9.82	7.133	0.7133	7	0.1	0.07133	45.52	60.69	39.31
7	**0.08**	**80**	8.365E-01	8.36	7.133	0.7133	5.96	0.1	0.07133	53.31	66.63	33.37
8	**0.085**	**85**	7.219E-01	7.21	7.133	0.7133	5.14	0.1	0.07133	58.91	69.30	30.7
9	**0.09**	**90**	6.308E-01	6.30	7.133	0.7133	4.49	0.1	0.07133	65.33	72.58	27.42
10	**0.095**	**95**	5.573E-01	5.57	7.133	0.7133	3.97	0.1	0.07133	71.57	75.33	24.67
11	**0.1**	**100**	4.973E-01	4.97	7.133	0.7133	3.54	0.1	0.07133	77.68	77.68	22.32
12	**0.105**	**105**	4.479E-01	4.47	7.133	0.7133	3.18	0.1	0.07133	83.69	79.70	20.3
13	**0.11**	**110**	4.066E-01	4	7.133	0.7133	2.85	0.1	0.07133	89.76	81.6	18.4
14	**0.115**	**115**	3.720E-01	3.72	7.133	0.7133	2.65	0.1	0.07133	95.19	82.77	17.23
15	**0.12**	**120**	3.426E-01	3.42	7.133	0.7133	2.43	0.1	0.07133	100.90	84.13	15.87
16	**0.125**	**125**	3.175E-01	3.17	7.133	0.7133	2.26	0.1	0.07133	106.38	85.10	14.9
17	**0.13**	**130**	2.959E-01	2.95	7.133	0.7133	2.10	0.1	0.07133	111.91	86.08	13.92
18	**0.135**	**135**	2.772E-01	2.77	7.133	0.7133	1.97	0.1	0.07133	117.30	86.88	13.12
19	**0.14**	**140**	2.610E-01	2.61	7.133	0.7133	1.86	0.1	0.07133	122.60	87.57	12.43
20	**0.145**	**145**	2.467E-01	2.46	7.133	0.7133	1.75	0.1	0.07133	127.98	88.26	11.74
21	**0.15**	**150**	2.341E-01	2.34	7.133	0.7133	1.66	0.1	0.07133	133.25	88.83	11.17
22	**0.155**	**155**	2.230E-01	2.23	7.133	0.7133	1.59	0.1	0.07133	138.38	89.27	10.73
23	**0.16**	**160**	2.131E-01	2.13	7.133	0.7133	1.51	0.1	0.07133	143.66	89.78	10.22

Table 2 is representation of 0.1mm Brass physical filter, which shows percent attenuation of gamma ray photons at various energy ranges with coherent scattering, and proves its possible or feasible utilization in most of Tc-99m SPECT imaging, as a source to reduce scatter components..

Graph 1

Graphical representation of 0.1 mm Zinc filter showing percent attenuation at various energy ranges of gamma photons with coherent scattering

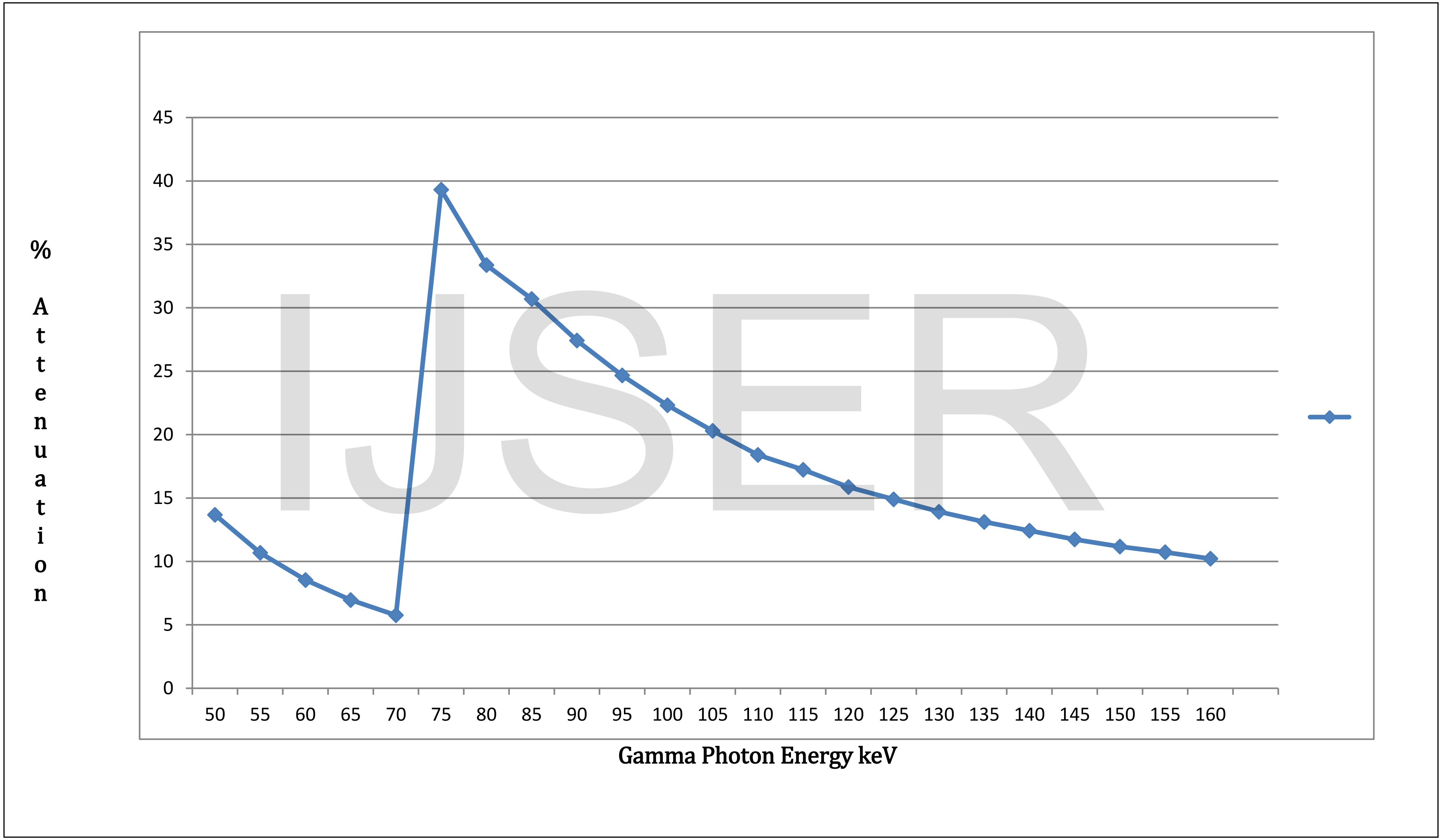


Table 3
0.1mm thin sheet of Zinc (Zn-30) showing transmission and percent attenuation at various energy ranges of gamma photons with out coherent scattering.

S..No.	Energy		Total mass attenuation coeff.		Density		Total Linear attenuation coefficient per mm	Thickness mm		Transmission		Percent attenuation
	MeV	keV	MeV	keV	Gram per cm cube	Milligram per mm cube		t mm	Mass thickness (Physical density multiplied by thickness)	Fraction	Percent	
1	**0.05**	**50**	2.737E+00	2.73	7.133	0.7133	1.94	0.1	0.07133	43.53	87.06	12.94
2	**0.055**	**55**	2.094E+00	2	7.133	0.7133	1.42	0.1	0.07133	49.70	90.36	9.64
3	**0.06**	**60**	1.646E+00	1.64	7.133	0.7133	1.16	0.1	0.07133	55.23	92.05	7.95
4	**0.065**	**65**	1.322E+00	1.32	7.133	0.7133	0.94	0.1	0.07133	60.78	93.50	6.5
5	**0.07**	**70**	1.084E+00	1	7.133	0.7133	0.71	0.1	0.07133	66.54	95,05	4.95
6	**0.075**	**75**	9.042E-01	9	7.133	0.7133	6.41	0.1	0.07133	48.40	64.53	35.47
7	**0.08**	**80**	7.664E-01	7.66	7.133	0.7133	5.46	0.1	0.07133	54.19	67.73	32.37
8	**0.085**	**85**	6.589E-01	6.58	7.133	0.7133	4.69	0.1	0.07133	60.83	71.56	28.44
9	**0.09**	**90**	5.738E-01	5.73	7.133	0.7133	4.08	0.1	0.07133	67.27	74.74	25.26
10	**0.095**	**95**	5.055E-01	5	7.133	0.7133	3.56	0.1	0.07133	73.69	77.56	22.44
11	**0.1**	**100**	4.501E-01	4.5	7.133	0.7133	3.20	0.1	0.07133	79.59	79.69	20.41
12	**0.105**	**105**	4.045E-01	4	7.133	0.7133	2.85	0.1	0.07133	84.95	80.90	19.1
13	**0.11**	**110**	3.668E-01	3.66	7.133	0.7133	2.61	0.1	0.07133	91.31	83	17
14	**0.115**	**115**	3.352E-01	3.35	7.133	0.7133	2.38	0.1	0.07133	97.04	84.38	15.60
15	**0.12**	**120**	3.086E-01	3	7.133	0.7133	2.13	0.1	0.07133	103.08	85.9	14.1
16	**0.125**	**125**	2.860E-01	2.86	7.133	0.7133	2.04	0.1	0.07133	108.07	86.45	13.55
17	**0.13**	**130**	2.666E-01	2.66	7.133	0.7133	1.89	0.1	0.07133	113.60	87.38	12.62
18	**0.135**	**135**	2.499E-01	2,49	7.133	0.7133	1.77	0.1	0.07133	118.98	88.13	11.87
19	**0.14**	**140**	2.354E-01	2.35	7.133	0.7133	1.67	0.1	0.07133	124.27	88.76	11.24
20	**0.145**	**145**	2.227E-01	2.22	7.133	0.7133	1.58	0.1	0.07133	129.54	89.33	10.67
21	**0.15**	**150**	2.116E-01	2.11	7.133	0.7133	1.50	0.1	0.07133	134.77	89.84	10.16
22	**0.155**	**155**	2.018E-01	2	7.133	0.7133	1.42	0.1	0.07133	140.06	90.36	9.64
23	**0.16**	**160**	1.931E-01	1.93	7,133	0.7133	1.37	0.1	0.07133	145.10	90.68	9.32

Table 3 is representation of 0.1mm Brass physical filter , which shows percent attenuation of gamma ray photons at various energy ranges without coherent scatterings, and proves its possible or feasible utilization in most of Tc-99m SPECT imaging, as a source to reduce scatter components.

Graph 2

Graphical representation of 0.1 mm thin sheet of Zinc showing percent attenuation at various energy ranges of gamma photons without coherent scattering.

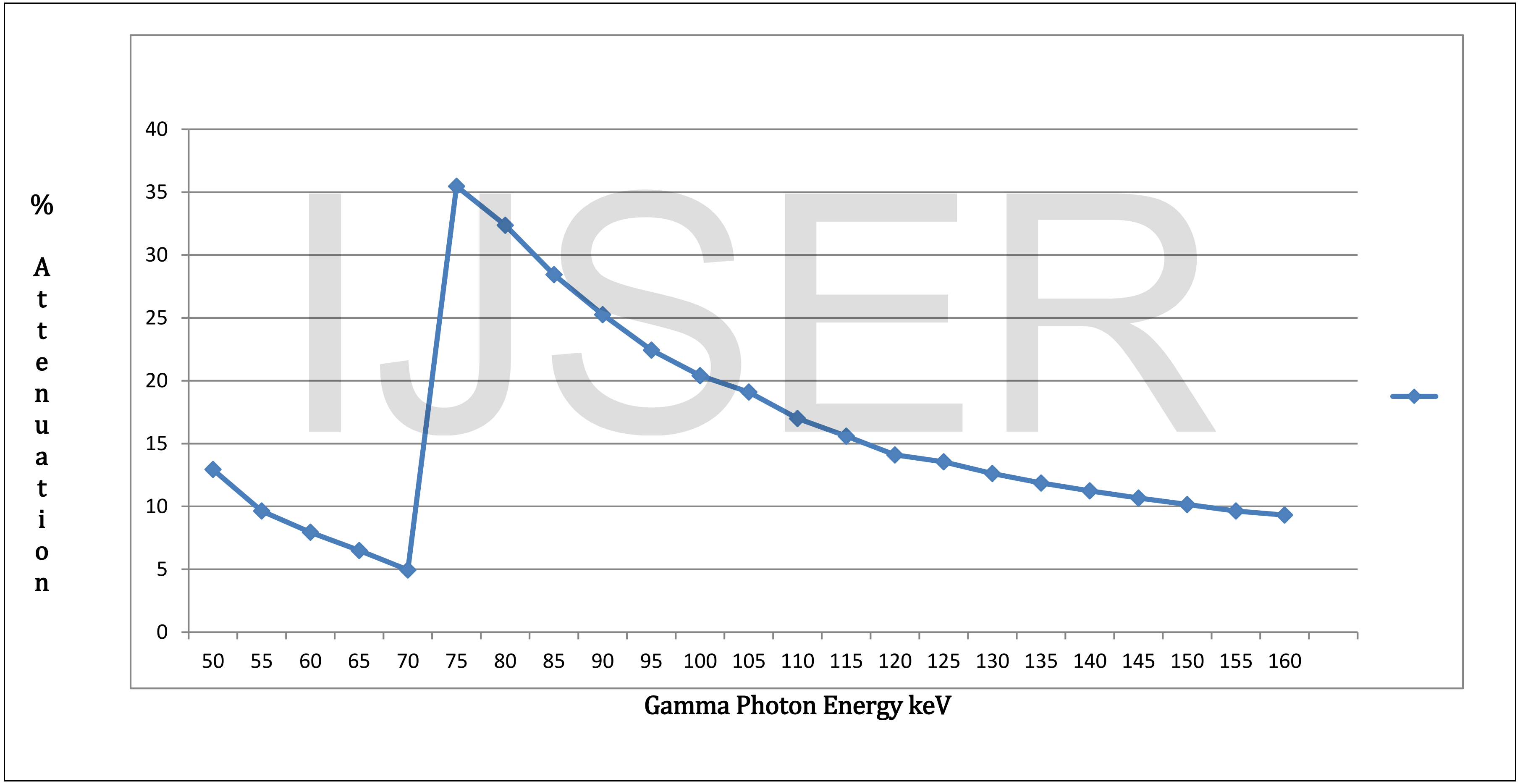


Table 4

0.2 mm Zinc filter showing percent attenuation at various energy ranges of gamma photons with coherent scattering.

S. No	Energy keV	Percent Attenuation
1	50	25.48
2	55	20.19
3	60	16.34
4	65	13.44
5	70	11.18
6	75	63.2
7	80	57.28
8	85	51.98
9	90	47.3
10	95	43.25
11	100	39.66
12	105	36.48
13	110	33.41
14	115	31.49
15	120	29.82
16	125	27.57
17	130	25.9
18	135	24.51
19	140	23.31
20	145	22.1
21	150	21.09
22	155	20.3
23	160	19.39

Table 4 is representation of 0.2mm Zinc physical filter, which shows percent attenuation of gamma ray photons at various energy ranges with coherent scattering, and proves its possible or feasible utilization in most of Tc-99m SPECT imaging, as a source to reduce scatter components..

Graph 3

Graphical representation of 0.2 mm Zinc filter showing percent attenuation at various energy ranges of gamma photons with coherent scattering

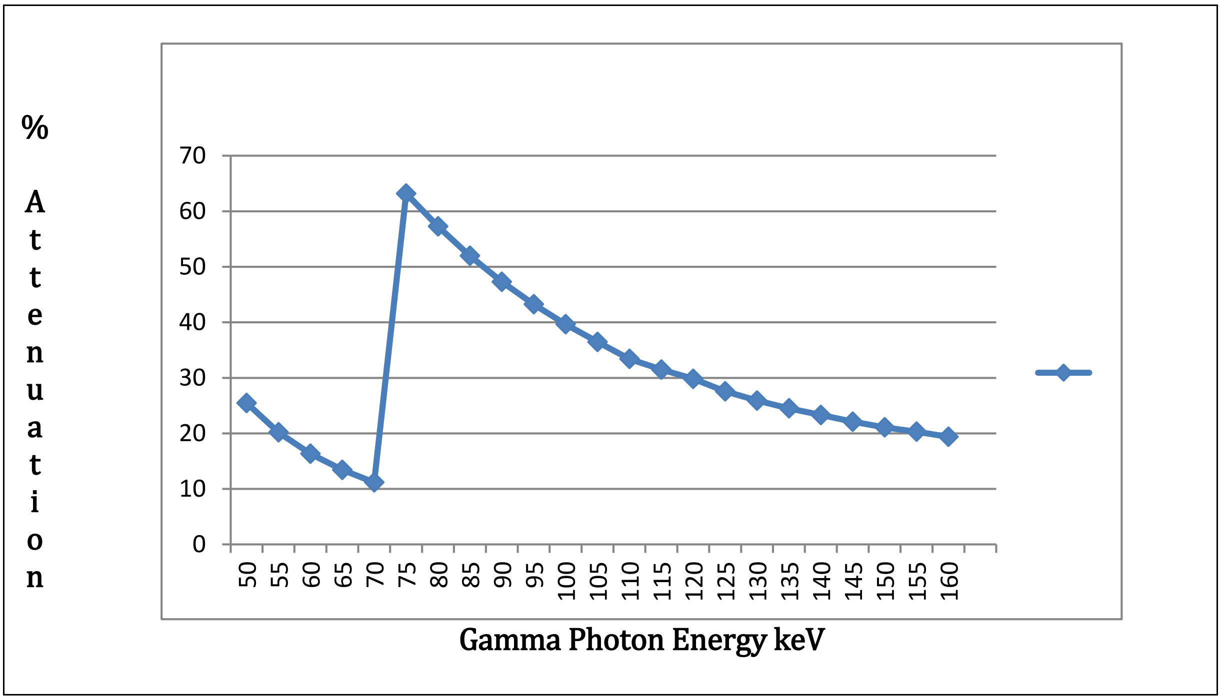


Table 5

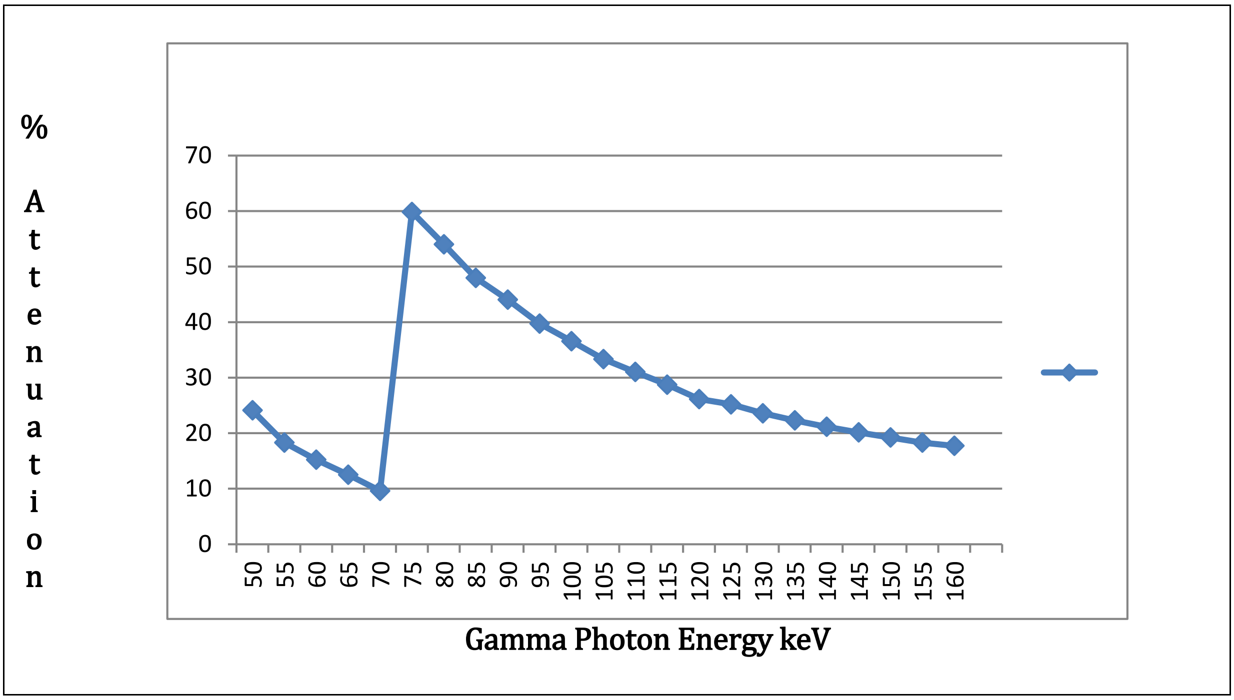
0.2 mm thin sheet of Zinc showing percent attenuation at various energy ranges of gamma photons without coherent scattering.

S. No	Energy keV	Percent Attenuation
1	50	24.12
2	55	18.31
3	60	15.22
4	65	12.53
5	70	9.62
6	75	59.83
7	80	54.02
8	85	47.96
9	90	44.05
10	95	39.74
11	100	36.57
12	105	33.34
13	110	31.02
14	115	28.73
15	120	26.15
16	125	25.20
17	130	23.58
18	135	22.30
19	140	21.15
20	145	20.14
21	150	19.22
22	155	18.30
23	160	17.72

Table 5 is representation of 0.2mm Zinc physical filter, which shows percent attenuation of gamma ray photons at various energy ranges without coherent scattering, and proves its possible or feasible utilization in most of Tc-99m SPECT imaging, as a source to reduce scatter components..

Graph 4

Graphical representation of 0.2 mm thin sheet of Zinc showing percent attenuation at various energy ranges of gamma photons without coherent scattering



2.2 Filter Performance

The main purpose of filter designing, analysis and implementation in SPECT data acquisition is to stop or prevent the detection of scattered gamma photons prior to reach the detecting surface of gamma camera crystal. The standard method for SPECT data acquisition is to set an electronic energy window 20% at FWHM of photopeak energy spectrum of radionuclide in use as shown in figure given below.

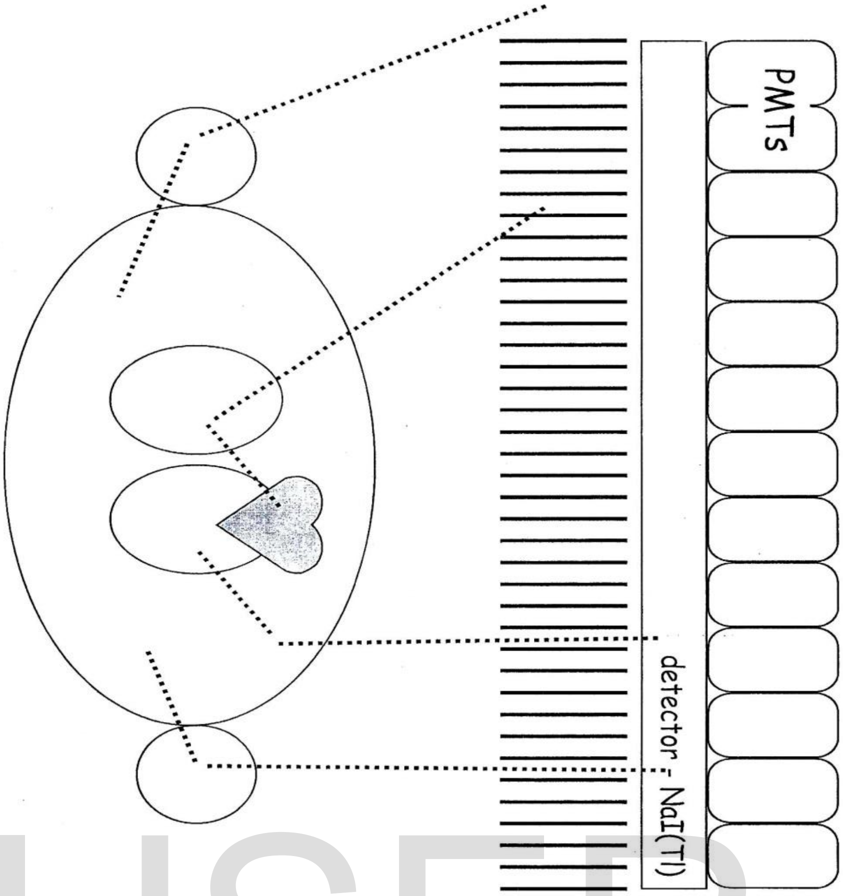


Figure 1
Data gathering via conventional method by (adjusting electronic energy window-EEW)

From above figure 1 it is clearly observed that, the data acquired by setting electronic energy window contains scattered (secondary) gamma photon.

To overcome this problem in SPECT data acquisition, some another techniques are required to be in practice in conjunction with electronic energy window. It is possible to use material based physical filter (thin flat sheet). As shown in figure below.

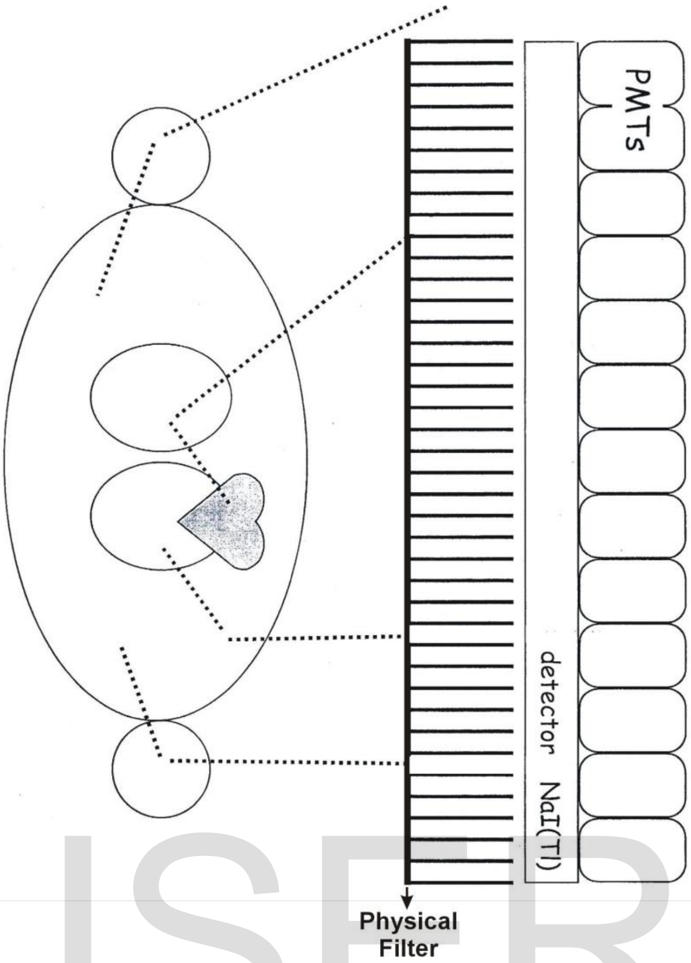


Figure 2
Data gathering via conventional method by (adjusting electronic energy window-EEW) in conjunction with physical filter

From above figure 2 it is most clearly observed that, by implanting physical filter in SPECT data acquisition have potential influence to reduce the scatter component by means of absorbing or attenuating the scattered events prior to registered within primary photopeak energy spectrum, resulting to produce more reliable SPECT data for clinical purpose.

03 Results and Discussion

The work presented in this paper is quite sufficient evidence of utilizing 0.1 and 0.2 mm thick Zinc flat sheets as a physical filter in Tc-99m SPECT imaging, to attenuates or absorbs low energetic (scattered) gamma photons in data acquisition. The proposed filter may stand as attenuating medium to prevent or block the scattered gamma photons, prior to reach the crystal detector surface of gamma camera. Hence resulting to produce qualitative SPECT images for clinical practice.

04. Conclusion

It is clearly observed and concluded from work presented in Table 2 to 5 and graph 1 to 4, that by implementing proposed filters in SPECT data acquisition will results to reduce some fraction of scatter components of various energies, hence better quality and contrast images for clinical practice may yield.

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