Assessment of Residual Radioisotopes Following F-18 Radionuclide Production

Imam Kambali

Center for Radioisotope and Radiopharmaceutical Technology
National Nuclear Energy Agency (BATAN)
Puspiptek Area, Serpong, South Tangerang, INDONESIA - 15314
Email: imamkey@batan.go.id

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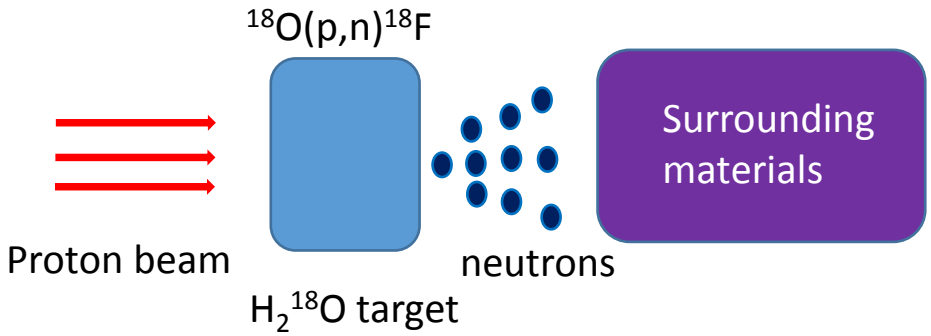
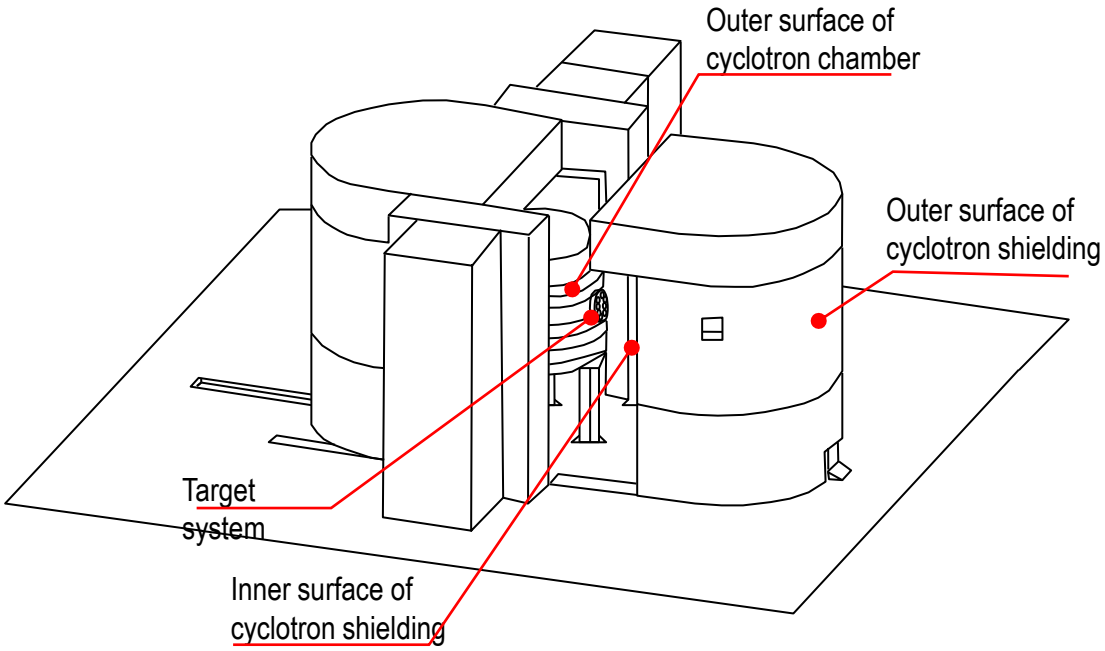
1. Introduction

- Fluorine-18 (F-18) is used in nuclear medicine for cancer diagnosis
- At Dharmais Cancer Hospital in Jakarta, F-18 is produced using an 11-MeV proton accelerating cyclotron
- F-18 production generates a vast number of secondary neutrons which are scattered off and/or transmitted into surrounding materials
- It could potentially generate residual radioisotopes in the cyclotron vicinity which eventually become major safety concerns over radiation exposure to the workers
- Radiation measurement and radioisotope identification are required

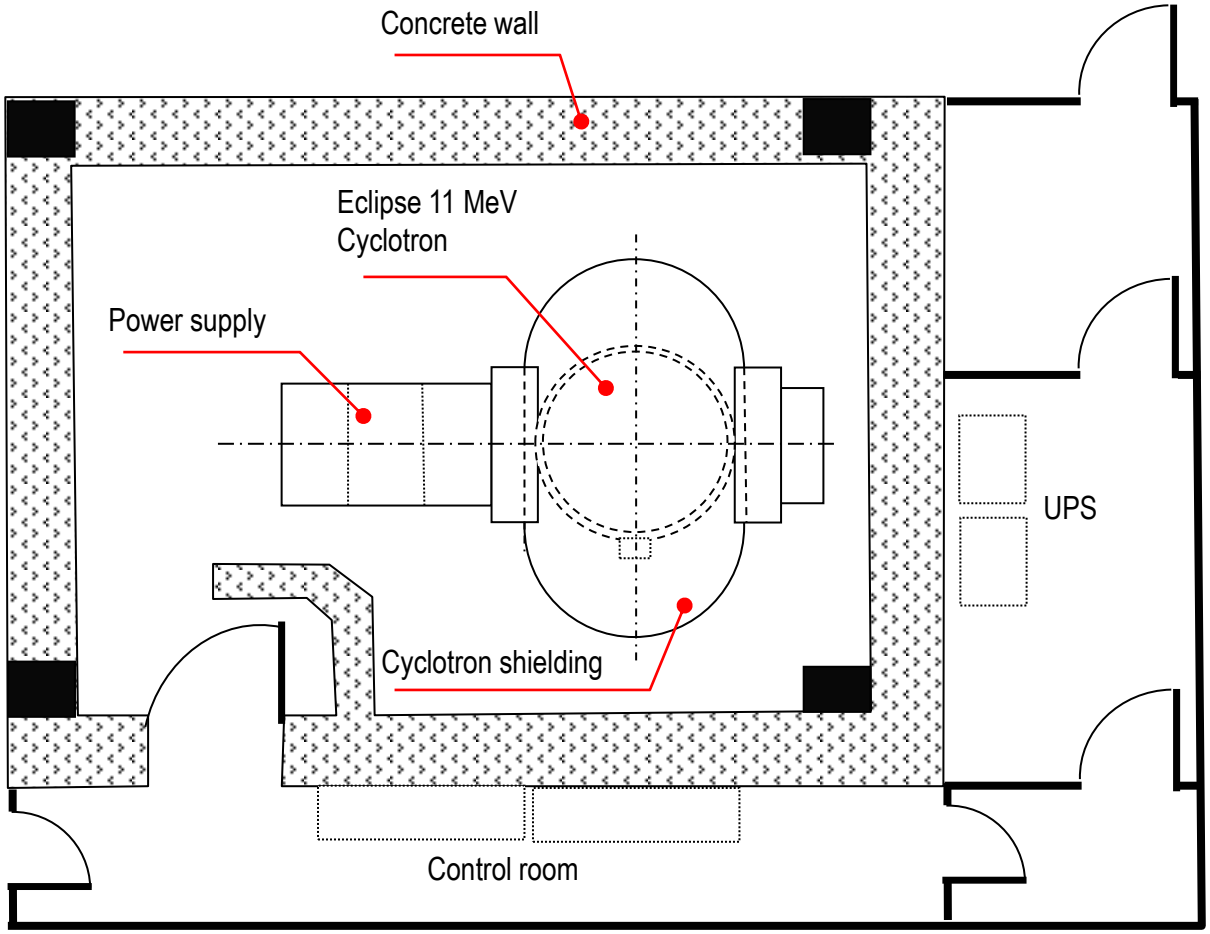


2. Experiments

- F-18 production was done using an 11-MeV cyclotron at Dharmais Cancer Hospital in Jakarta, Indonesia
- Residual radionuclides in post-irradiated $H_2{}^{18}O$ were detected
- Radiation in the cyclotron vicinity were detected, including the cyclotron's shielding, cyclotron tank/chamber, cave wall as well as target system

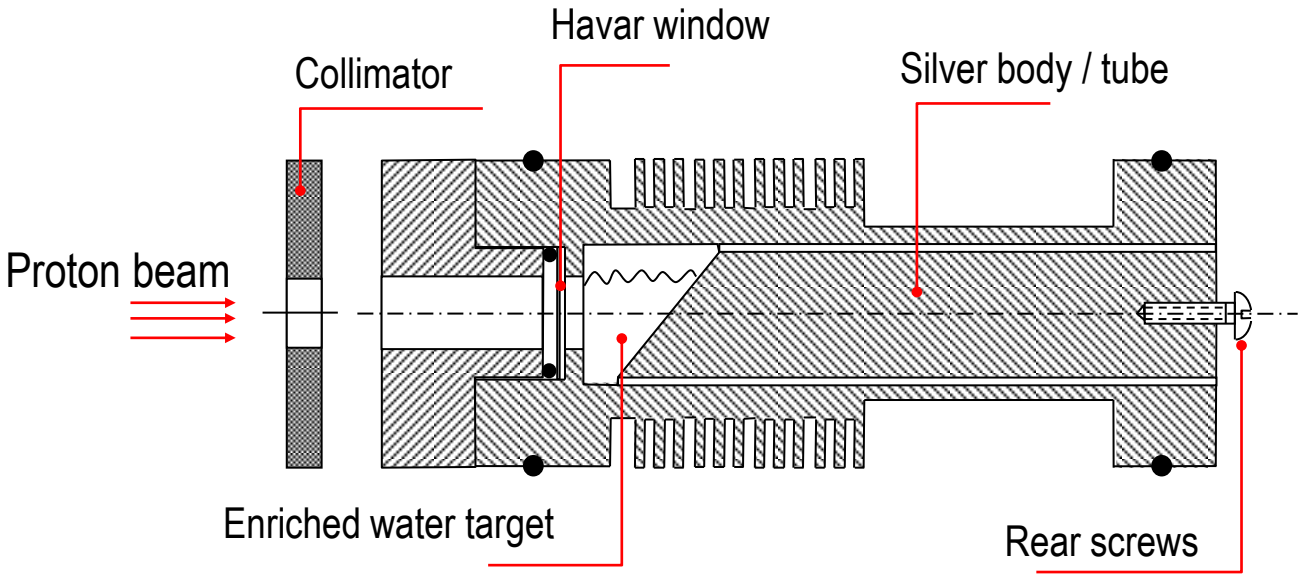


2. Experiments



11-MeV cyclotron cave in Dharmais Cancer Hospital, Jakarta

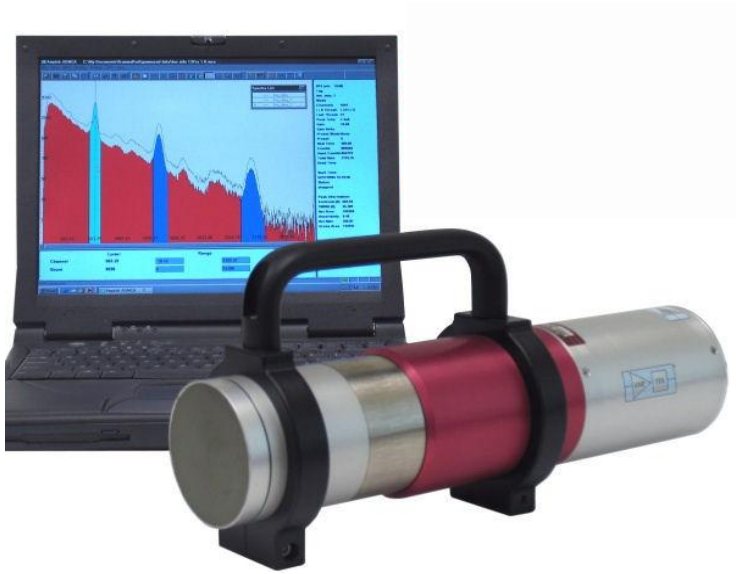
2. Experiments



Target system for F-18 production at Dharmais Cancer Hospital, Jakarta

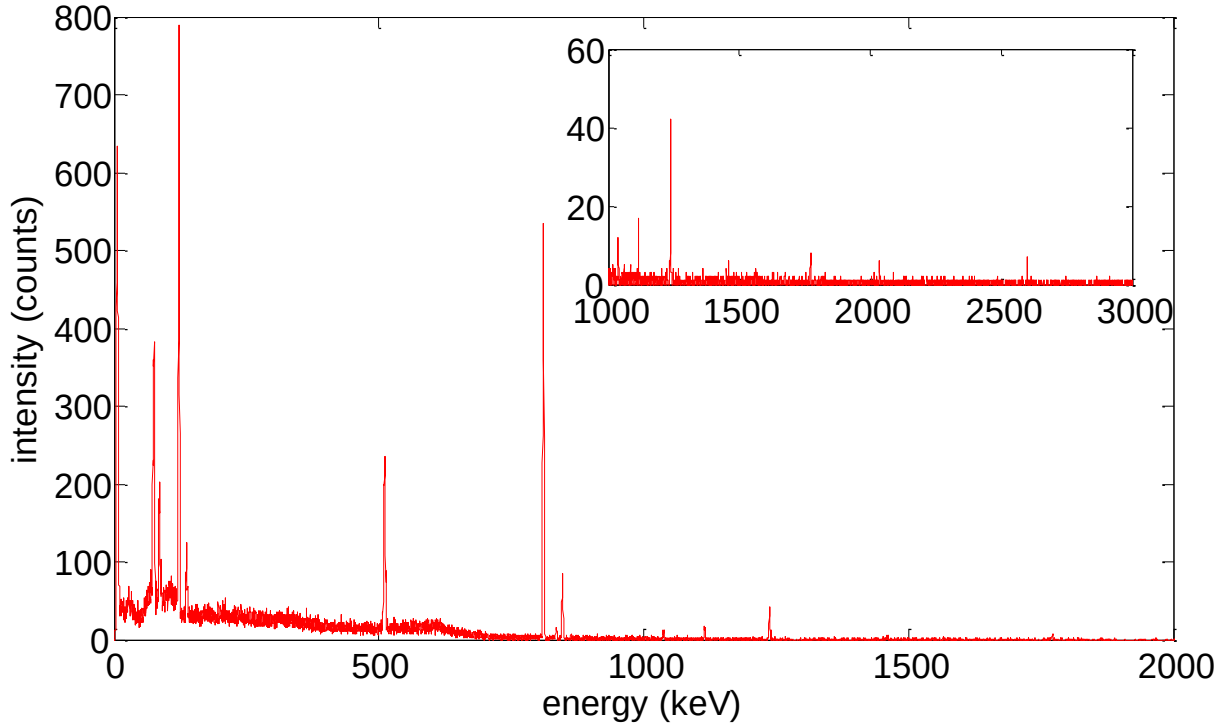
2. Experiments

- Radiation detection and measurement was performed using HPGe based gamma ray spectrometer and NaI based portable gamma ray spectrometer
- TALYS Evaluated Nuclear Data (TENDL 2015) were employed to study the origin of residual radioisotopes



3. Results and Discussion

3.1 Gamma spectrum of residual radioisotopes detected in Irradiated $H_2{}^{18}O$



- Sample was measured 2 days following F-18 production
- Measurement was done using HpGe based gamma spectroscopy system

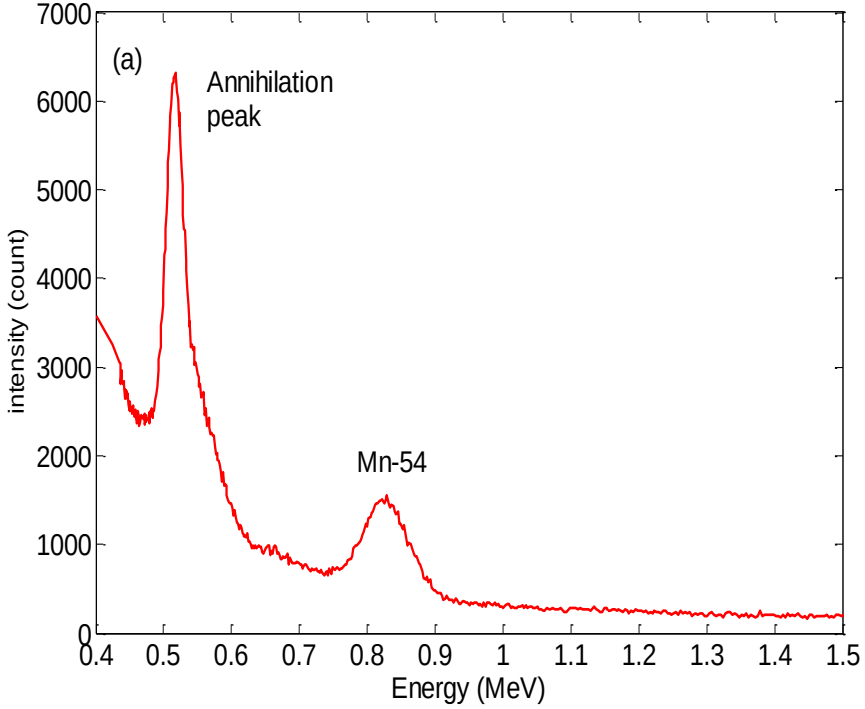
3. Results and Discussion

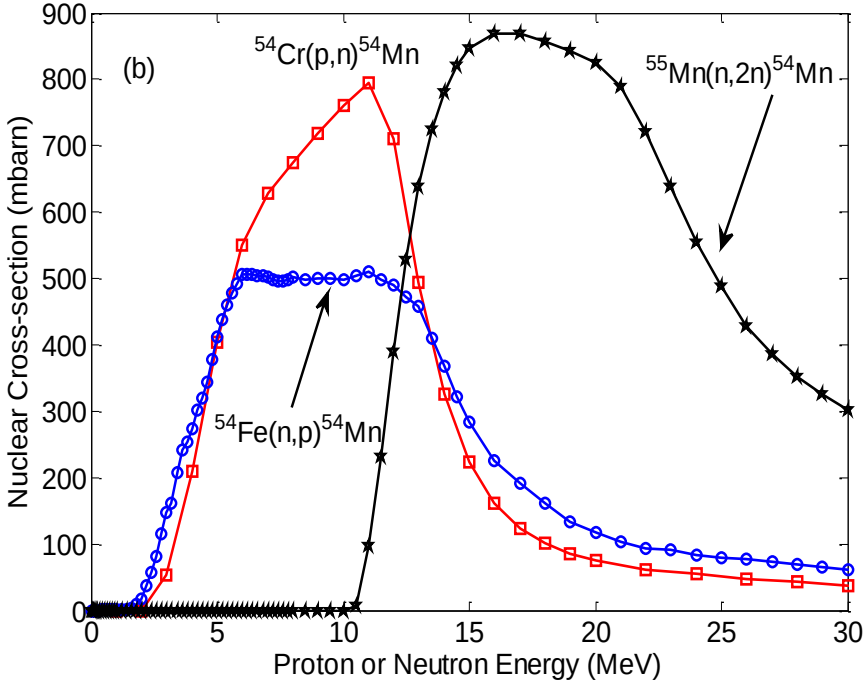
3.1 Residual Radioisotopes Detected in Irradiated $H_2{}^{18}O$, 2 Days Following F-18 Production

Radio-nuclide	$T_{1/2}$ (days)	Eγ (keV)	Nuclear Reaction	Source
^{57}Co	271.8	122	$^{60}Ni(p,\alpha)^{57}Co$; $^{58}Ni(p,2p)^{57}Co$; $^{58}Ni(n,2n)^{57}Co$	Havar
^{57}Ni	1.496	511, 1378	$^{58}Ni(p,pn)^{57}Ni$; $^{58}Ni(p,d)^{57}Ni$; $^{59}Co(p,X)^{57}Ni$	Havar
^{58}Co	70.83	811	$^{58}Fe(p,n)^{58}Co$; $^{58}Ni(n,p)\,^{58}Co$; $^{59}Co(n,2n)\,^{58}Co$	Havar
^{54}Mn	312.1	835	$^{58}Fe(n,p)^{54}Mn$; $^{55}Mn(n,2n)\,^{54}Mn$	Havar
^{56}Co	77.24	847	$^{56}Fe(p,n)^{57}Co$; $^{56}Fe(p,2n)^{57}Co$	Havar
^{55}Co	0.730	931, 2557	$^{58}Ni(p,\alpha)^{55}Co$	Havar
^{52}Mn	5.591	936, 1434	$^{52}Cr(p,n)^{52}Mn$	Havar
^{48}V	15.974	983, 1312	$^{49}Ti(p,2n)^{48}V$	Havar
^{110}Ag	250	657, 885, 937	$^{109}Ag(n,\gamma)^{110}Ag$	Silver body

3. Results and Discussion

3.1 Radiation Detected in the Outer Surface of the Cyclotron Chamber

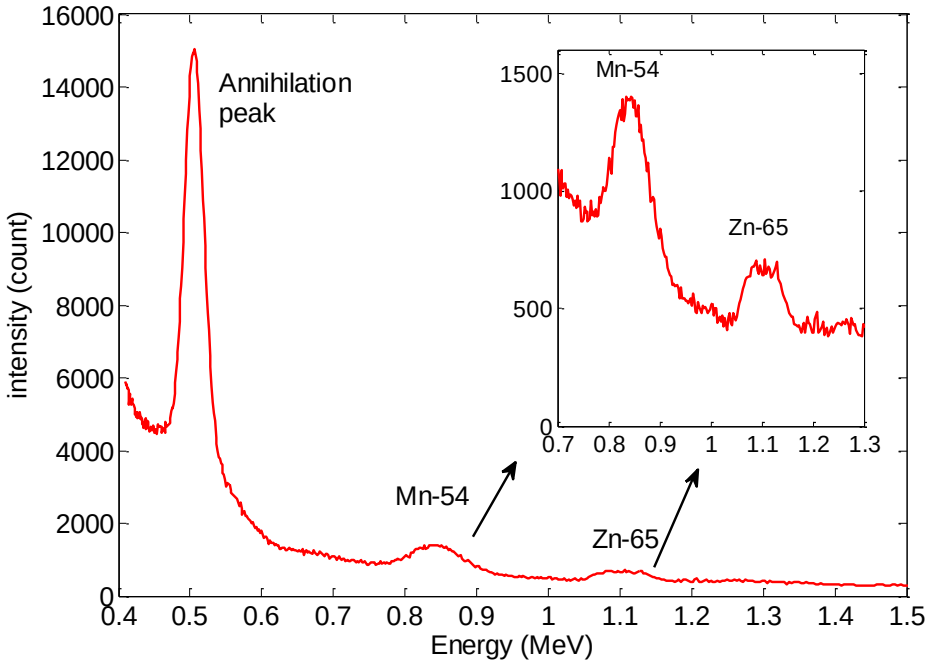


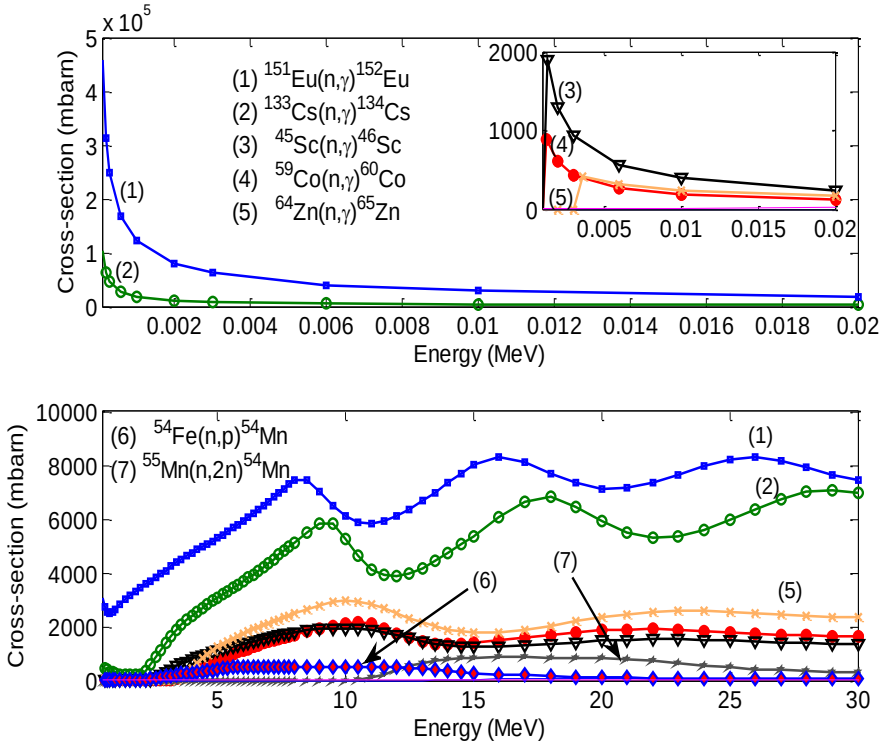


(a) Gamma ray emissions detected in the outer surface of the cyclotron chamber (at 90^{o} with respect to the incoming proton beam), and **(b)** TALYS-calculated nuclear cross-sections of ^{54}Cr(p,n)^{54}Mn, ^{54}Fe(n,p)^{54}Mn, and ^{55}Mn(n,2n)^{54}Mn reactions.

3. Results and Discussion

3.2 Radiation Detected in the Inner Surface of the Shielding

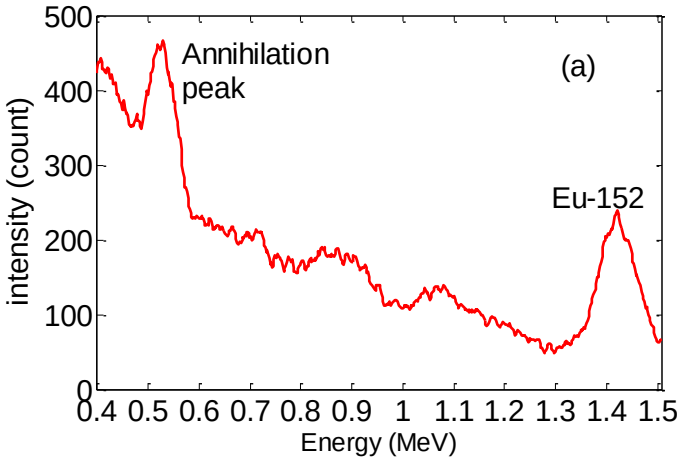


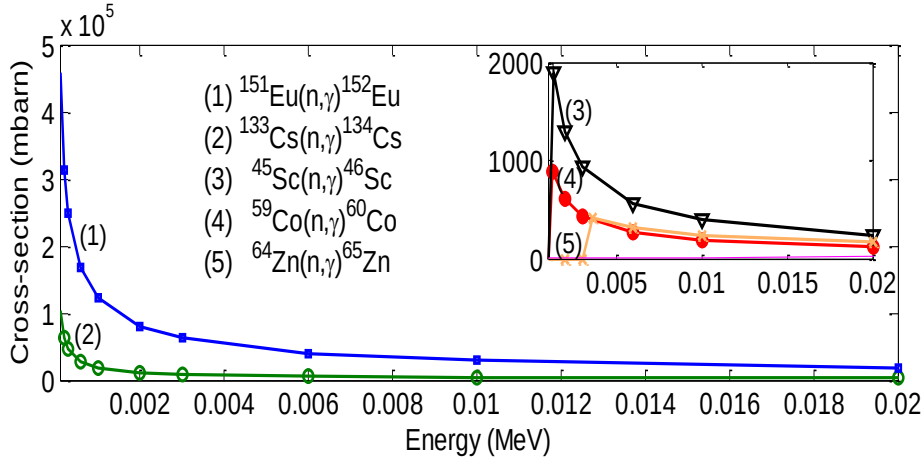


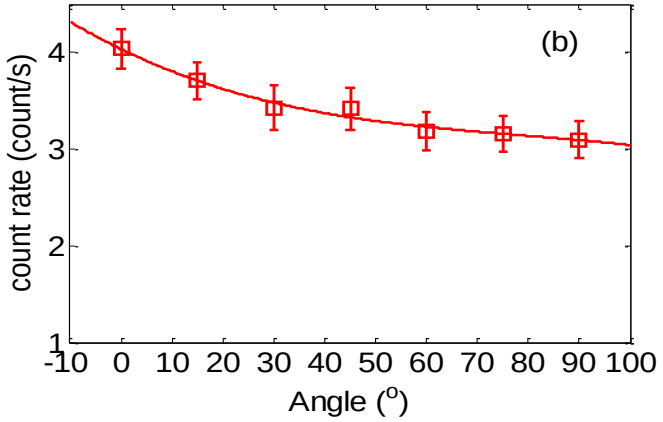
(a) Gamma ray emissions detected in the inner surface of the Eclipse 11 cyclotron's shielding
(b) TALYS-calculated nuclear cross-sections of several trace elements present in the shielding and wall of the cyclotron cave in Dharmais Cancer Hospital, Jakarta

3. Results and Discussion

3.2 Radiation Detected in the Outer Surface of the Shielding







(a) Gamma ray emissions detected in the outer surface of the Eclipse 11 cyclotron's shielding

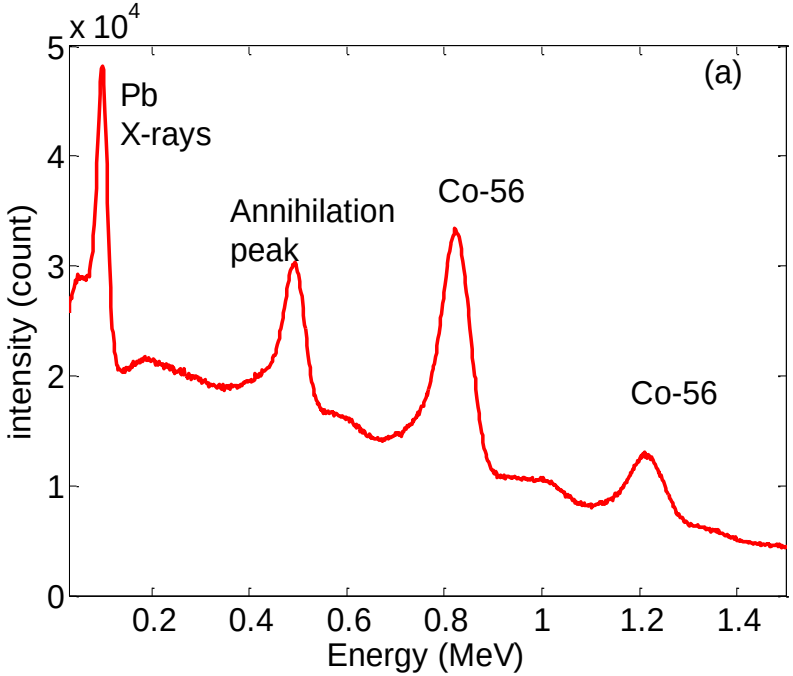
(b) Angular distribution of the Eu-152 gamma ray intensities

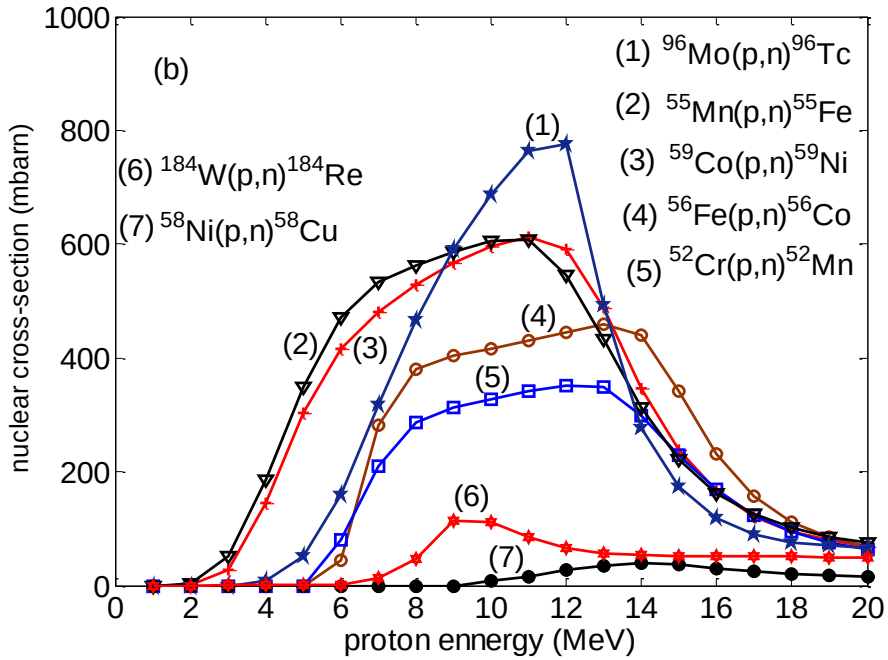
(c) TALYS-calculated nuclear cross-sections of several trace elements present in the shielding and wall of the cyclotron cave in Dharmais Cancer Hospital, Jakarta

3. Results and Discussion

3.3 Radiation Detected in the Target System

3.3.1 Havar window



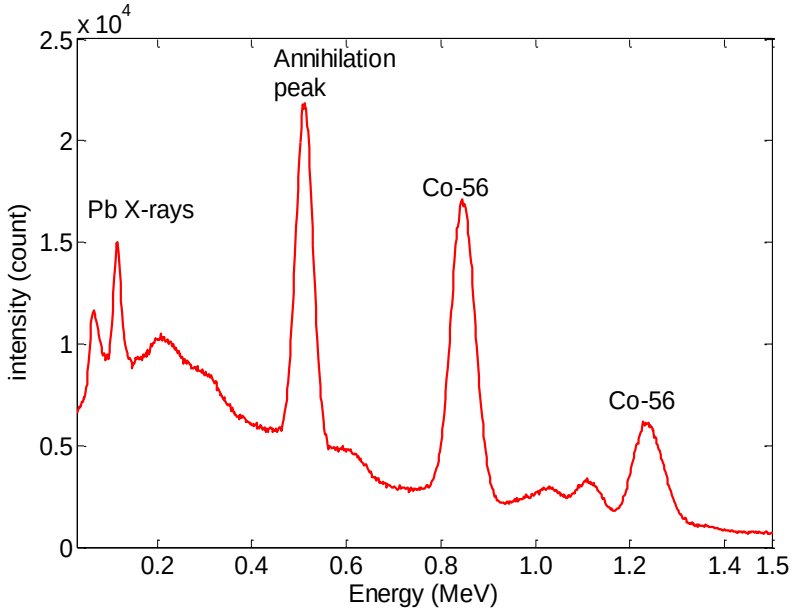


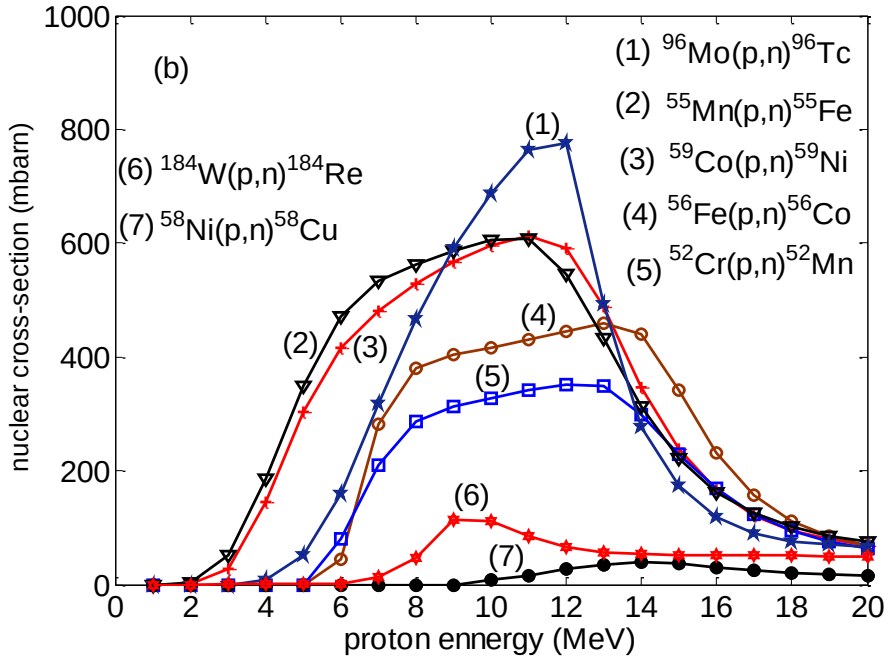
(a) Gamma ray emissions detected in the Havar window, and
(b) (b) TALYS-calculated nuclear cross-sections of possible proton-induced radionuclides

3. Results and Discussion

3.3 Radiation Detected in the Target System

3.3.2 Collimator



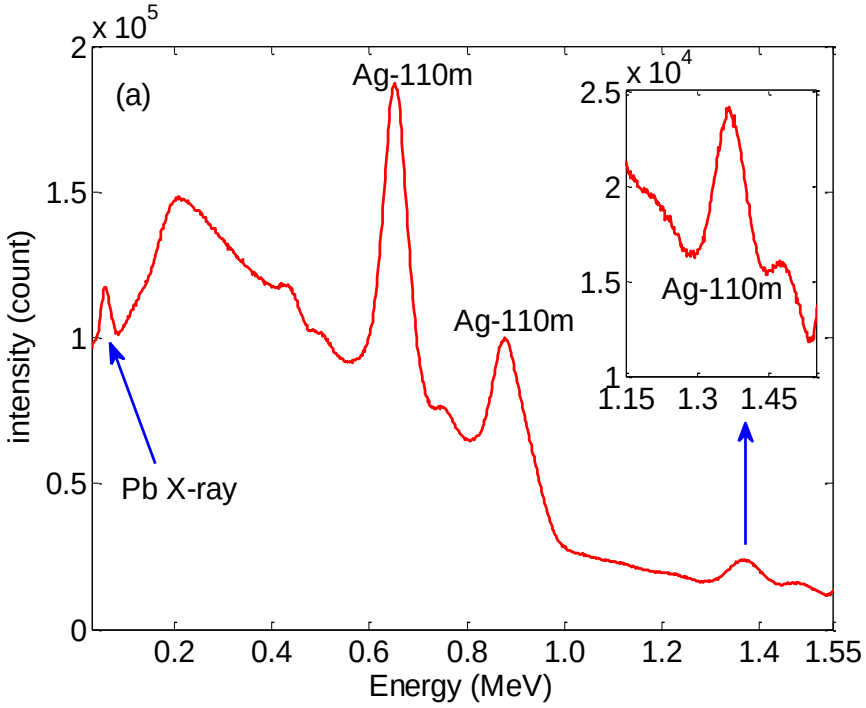


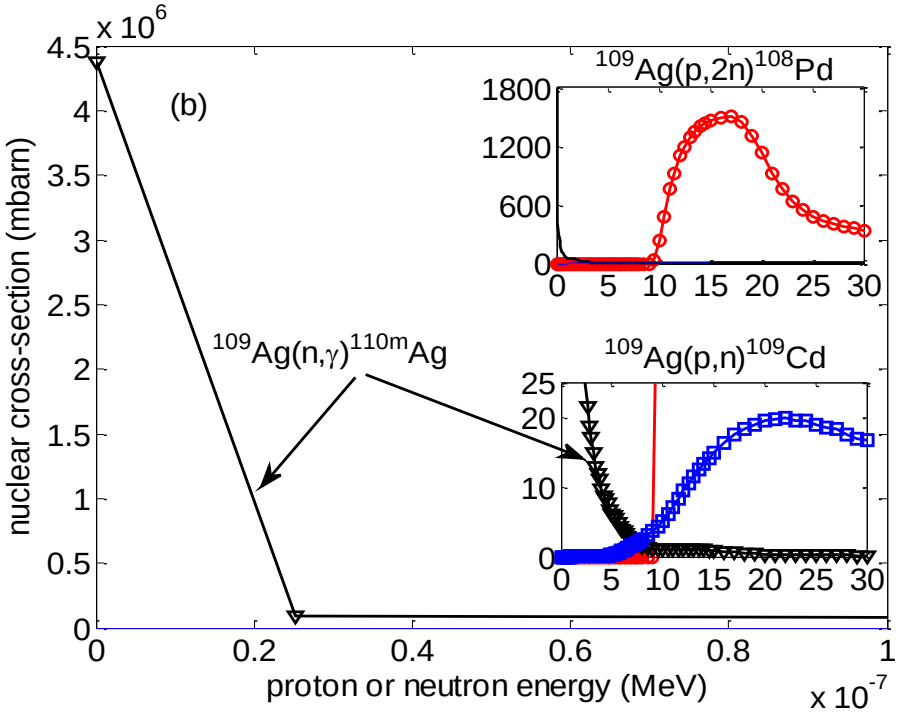
Gamma ray emissions captured by the portable gamma ray spectrometry system from the collimator in the target system

3. Results and Discussion

3.3 Radiation Detected in the Target System

3.3.3 Target Body



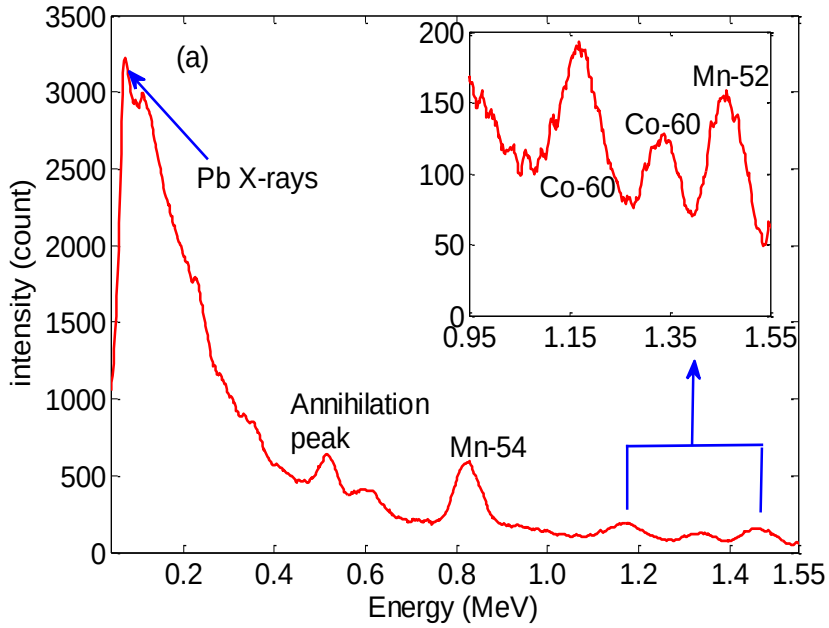


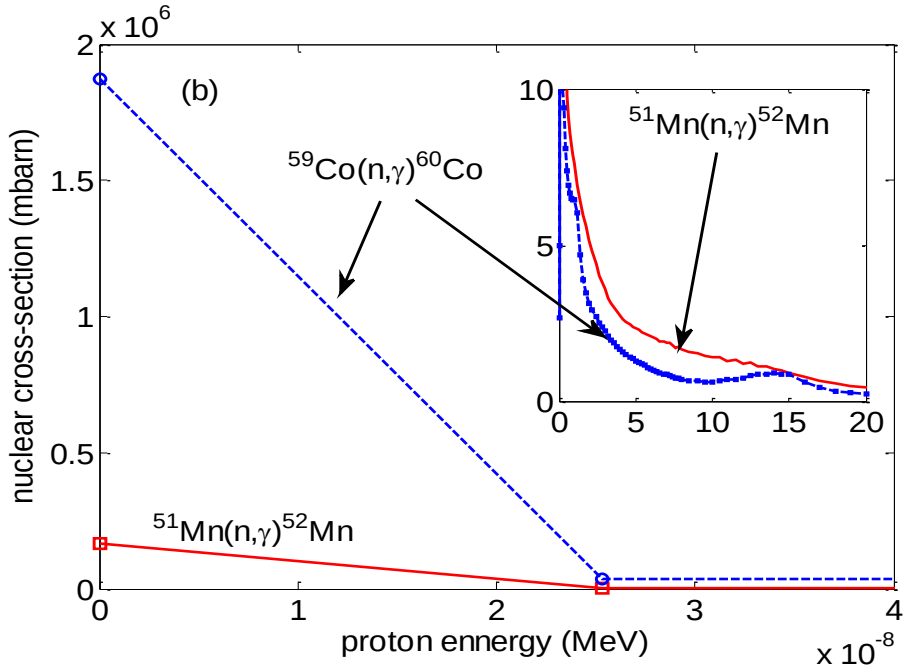
(a) Gamma ray emissions detected in the silver body, and
(b) TALYS-calculated nuclear cross-sections of $^{109}Ag(n,\gamma)^{110m}Ag$, $^{109}Ag(p,n)^{109}Cd$ and $^{109}Ag(p,2n)^{108}Pd$ nuclear reactions

3. Results and Discussion

3.3 Radiation Detected in the Target System

3.3.4 The Rear Screw





(a) Gamma ray emissions detected in the rear screw of the target system, and
(b) TALYS-calculated nuclear cross-sections of ^{51}Mn(n,γ)^{52}Mn and ^{59}Co(p,n)^{60}Co

4. Conclusion

Proton and neutron induced by-products identified in the Dharmais Cancer Hospital, Jakarta

No	Investigated Component/Point	Observed Radionuclide	Nuclear Reaction
1.	Outer surface of the cyclotron chamber	Mn-54	$^{54}Fe(n,p)^{54}Mn$
2.	Inner and outer surface of the cyclotron shielding	Zn-65	$^{64}Zn(n,\gamma)^{65}Zn$
		Mn-54	$^{54}Fe(n,p)^{54}Mn$ and/or $^{55}Mn(n, 2n)^{54}Mn$
		Eu-152	$^{151}Eu(n,\gamma)^{152}Eu$
3.	Havar windows and collimator	Co-56	$^{56}Fe(p,n)^{56}Co$
4.	Silver body	Ag-110m	$^{109}Ag(n,\gamma)^{110m}Ag$
5.	Rear screws	Mn-52,	$^{51}Mn(n,\gamma)^{52}Mn$
		Co-60,	$^{59}Co(n,\gamma)^{60}Co$
		Mn-54	$^{54}Fe(n,p)^{54}Mn$ and/or $^{55}Mn(n, 2n)^{54}Mn$

Thank You

Grazie

Terima kasih