Calculation of Nuclear Reaction Cross Section of Proton Induced Reaction of Silicon Isotopes from 1-30mev

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ABSTRACT

Nuclear models calculation of excitation functions was performed and evaluated using the nuclear theoretical model code EXIFON. The EXIFON code, which is based on the analytical model for statistical multistep direct and statistical multistep compound reactions (SMD/SMC model), Investigation concerning the shell structure on proton induced reaction cross section of silicon isotopes ^{28,29,30}Si in the energy range of 1-30MeV has been made. Results are benchmark and validated with data from the experimental database (EXFOR), and evaluated database (ENDF) from the International Atomic Energy Agency (IAEA) nuclear data bank. The results obtain shows that proton induced reaction has a high cross section in the interaction, which also arises from high energy protons, largely due to the large fluxes and the interaction cross section.

Keywords: Cross-section, Evaluated data, Experimental data, Exifon code.

INTRODUCTION

Nuclear reaction cross section is one of the most important quantities which we encounter easily in nuclear reactions. It can simply be defined as the probability of interaction. Therefore, the chance that a reaction of a specific type will occur, or more simply put, the probability that the reaction will occur, is represented by the cross section for that reaction. The cross-section for absorption, scattering, and fission can be defined as follows: absorption cross-section, scattering cross-section, and fission cross-section. We can now define the cross section, σ of any reaction simply as:

$$\sigma = \frac{\text{Number of events of a given type per nucleus}}{\text{Number of incident particle per unit time}}$$

In nuclear physics, the likelihood that nuclear reactions and other collision events will occur can be measured using the cross-section [4]. Imagine an incident, collimated particle beam that impacts target nuclei in an appropriate specimen of material. The beam interacts with the target nuclei by mechanisms including absorption, reaction, and/or scattering, causing them to become attenuated. Measurements taken on the emerging beam can be used to assess how much the intensity, energy, or both have been attenuated. The most simplistic method to imagine the possibility of interaction is to imagine the incident beam as composed of point particles that, should they hit a target nucleus directly, will initiate an interaction; if they miss the target nucleus, they will continue on their journey without causing any problems. This simplistic idea, however, ignores the finite contact radius and the finite extension of the impinging particles, which are likely to extend much beyond the immediate boundaries of the target nucleus. Hence rather than treating the geometrical cross sectional area of a nucleus (πR^2) (where R is the nucleus radius), It is measured in barns (1 barn $=10^{-28}$ m²), as a measure of interaction probability, Attributing an effective area perpendicular to the incident beam to each nucleus makes sense since it ensures that, in the event that a bombarding particle strikes any portion of this hypothetical disk, an interaction will happen; otherwise, none at all.

Statistical Multistep Direct (SMD)

For the incident-energy range below 30 MeV we restrict ourselves to one and two-step contributions since the SMD process terminates after few collisions. According to the distinction between non-collective particle-hole excitations and collective vibrational states the SMD cross section becomes a sum of 2 one-step and 4 two-step contributions (b = n, p)

$$\frac{d\sigma_{ab}^{SMD}(E_a)}{dE_b} = \frac{\mu_a \mu_b r^2}{(2\pi\hbar^2)^2} \frac{4\pi}{(K_{a}R)^2} \frac{K_b}{K_a} \mathcal{P}_a(E_a)\, \mathcal{P}_b(E_b) \sum_{(Y)} Y \qquad (1)$$

Where [Y] symbolizes the individual contributions denoted according to the sequence of exciton and phonon excitations.

Statistical Multistep Compound (SMC)

The SMC cross section has the familiar form (b = n, p,α, γ)

$$\frac{d\sigma_{ab}^{SMC}(E_a)}{dE_b} = \sigma_a^{SMC}(E_a) \sum_{N=No}^{N} \frac{\tau_N(E)}{\hbar} \Gamma_{NB}(E,E_b)\uparrow. \qquad (2)$$

Where τ_N(E) satisfies the time-integrated master equation,

The following nuclear structure effects are included in the SMC description:

(i) Pairing effects. For a system of A=N+Z nucleons the effective neutron (proton) binding energy is defined by

$$B_{n(p)}^{eff} = \begin{cases} B_{n(p)} + \Delta \\ B_{n(p)} - \Delta \end{cases} for \; {}^{odd}_{even} \; N\,(Z) \qquad (3)$$

Where $B_{n(p)}$ is the neutron (proton) binding energy, and Δ=12$A^{-1/2}$ MeV. For α- and γ-emission we use B_α^{eff}= B_α and B_γ^{eff}= 0. The effective binding energy is used, as well as for the definition of the (effective) excitation energy, E=E_a+E_a^{eff}.

(ii) Pauli blocking effects. The excitation energies E and U are replaced by E-A_{ph}, U-$A_{p-1,h}$ (for particle emission), and U-A_{ap} (for γ-emission). The energy shift is defined by $A_{ph} = (N_p^2$+N_p+N_h^2-3N_h)/4g.

(iii) Shell-structure effects. The constant single-particle state density g = 2(2s+1) $\rho(E_F)$ = A/13 (in MeV^{-1}) will be multiplied by an energy-dependent factor which leads to [2],

$$g\,(8) = g\,(1+ \frac{\delta W}{g}\,(1-\exp\,(-0.05/8))) \qquad (4)$$

With δW as the shell correction. The quantity g = E or U denotes here the excitation energy of the nuclear composite or residual systems.

(iv) Low energy behaviour. The probability through the nuclear barrier is considered by the additional factor [1]

$$\mathcal{P}_c(E_c) = 4K_C K\,(K + K_c)^{-2} \qquad (5)$$

In the ingoing and outgoing channels. K= [2μ (E+E_F)]$^{1/2}$ / h is the wave number inside the nucleus.

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MATERIAL AND METHOD

The EXIFON Code is the main source material. A wide range of applications, including nuclear reactions, nuclear structure, nuclear masses, decay data, product yields, medical radiation doses, astrophysical rates, etc., make the solitary SMD/SMC model code helpful for the evaluation of nuclear data. Each sort of data evaluation adheres to a set of identical guidelines and procedures while being specific. In this research, we mainly discuss how to use EXIFON CODE for the examination of nuclear reaction data. An analytical model for statistical multistep direct and multistep compound reactions serves as the foundation for the EXIFON CODE. It predicts the activation cross sections, angular distributions, and emission spectra of photons, protons, neutrons, and alpha particles. Up to three decays of the compound system are taken into consideration for multiple particle emissions.

EXIFON is a fast and simple-to-use code that uses a single global parameter set to anticipate cross sections. The only adjustable quantity is the pairing shift. It is also possible to arrange the EXIFON output in ENDF/B-6 format.

Calculation and Procedure

The software package EXIFON, which is based on the concept of optical potential (OM) of the statistical multistep direct (SMD), statistical multistep compound (SMC), and multi particle emission processes (MPE), was utilized for computational nuclear data physics. For neutrons, protons, alphas, and photons, it predicts emission spectra, angular distributions, and activation cross sections, including equilibrium, pre-equilibrium, and direct (collective and non-collective) processes. Emission of multiple particles is regarded as the compound system's up to three decay. The model is limited to reactions that are triggered by neutrons, protons, alpha particles, and photons in the outgoing channels. The range of validity includes bombardment energy below 30 MeV with mass numbers A > 20. [3].

The calculations were performed by Exifon code for the following different isotopes of Silicon.

Silicon 28	**Silicon 29**	**Silicon 30**

The following potential proton-induced reaction activation cross-sections, (p, p), (p, a), and (p, 2n), or proton-proton, proton-alpha, and proton-neutron, respectively, were taken into consideration in the energy range of 1–30 MeV based on the information that was accessible in the Code.

When the program is run, the target nucleus must be specified after the input and output directories have been defined. For this calculation, the incident particles—proton must be chosen first, and then the excitation function in the general option section.

The incident energy step is also mentioned (in MeV), after which comes the number of incident energy and the initial incident energy (in MeV).

The most crucial component of this computation, the shell structure effect, is chosen in the modification phase. There are two options: WITH and WITHOUT shell effect.

For each target nucleus, the option with shell effect must first be chosen. The output data (OUTEXI) for the calculation is then saved in the designated output directory. The set output directory contains the DAT file names A2N, ALF, and AP (for the proton-neutron, proton-Alpha, and proton-proton reactions, respectively).

Second, an output data (OUTEXI) for the calculation is then saved in the specified output directory for each target nucleus that is part of the option without shell impact. Additionally, the set output directory contains DAT files with the names A2N, ALF, and AP (Proton-2Neutron, Proton-Alpha, and Proton-Proton reaction, respectively). After that, the data in the DAT files can be read with a DAT file viewer or plotted as graphs or conversations.

Shell Structure Effects

Under such situation, the shell effects structure are reflecting in Statistical Multistep Compound (SMC) processes.

$$(1+\frac{\delta W}{E_X}\ [\ 1 - exp\ (-\gamma E_X)]) \quad (6)$$

Where γ = 0.05MeV^{-1} and δW are the shell correction energy, where the quantity E_X= E *or* U which denotes the excitation energy of the residual systems respectively.

The calculations were performed with ($\delta W \neq 0$) and without (δW = 0) shell corrections. The procedures WITH and WITHOUT correction of shell were repeated several times and the results of cross sections were obtained.

RESULT AND DISCUSSION

Table 1: Cross section for Proton induced reactions of Si28 with energy range of 1-30MeV from EXIFON code.

Element	**Energy (MeV)**	**Cross Section with Shell Correction (mb)**			**Cross Section Without Shell Correction (mb)**		
		(p, p)	**(p, a)**	**(p, 2n)**	**(p, p)**	**(p, a)**	**(p, 2n)**
	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	152.20	0.00	0.00	152.55	0.00	0.00
	3.00	296.62	0.00	0.00	296.67	0.00	0.00
	4.00	442.49	0.00	0.00	442.52	0.00	0.00
	5.00	580.05	0.00	0.00	580.07	0.00	0.00
	6.00	673.57	0.00	0.00	673.59	0.00	0.00
	7.00	737.72	0.00	0.00	737.73	0.00	0.00
	8.00	783.50	0.00	0.00	783.52	0.00	0.00
	9.00	817.05	0.00	0.00	817.06	0.00	0.00
	10.00	842.02	0.00	0.00	842.03	0.00	0.00
	11.00	860.77	0.00	0.00	860.78	0.00	0.00
	12.00	873.90	0.94	0.00	874.14	0.70	0.00
	13.00	881.48	3.81	0.00	882.45	2.86	0.00
	14.00	884.38	8.55	0.00	886.54	6.41	0.00
	15.00	884.42	13.89	0.00	887.86	10.46	0.00
Si28	16.00	881.09	20.67	0.00	886.14	15.66	0.00
	17.00	873.29	27.45	0.00	880.72	20.92	0.00
	18.00	862.98	34.31	0.00	872.77	26.34	0.00
	19.00	851.36	41.00	0.00	863.50	31.78	0.00

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	20.00	838.97	47.60	0.00	853.22	37.25	0.00
	21.00	826.57	53.96	0.00	842.60	42.65	0.00
	22.00	813.11	60.33	0.00	830.83	48.14	0.00
	23.00	799.35	66.51	0.00	818.53	53.58	0.00
	24.00	785.12	72.64	0.00	805.65	59.04	0.00
	25.00	770.82	78.47	0.00	792.50	64.32	0.00
	26.00	756.63	84.03	0.00	779.27	69.42	0.00
	27.00	742.12	89.34	0.00	766.92	73.49	0.00
	28.00	728.97	93.47	0.00	753.59	77.92	0.00
	29.00	715.02	97.84	0.00	740.27	82.04	0.00
	30.00	701.11	101.91	0.00	726.90	85.92	0.00

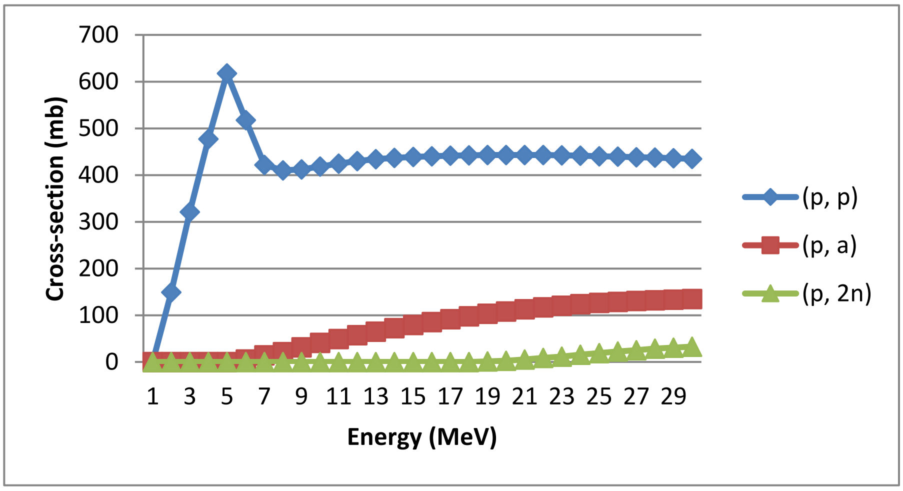

Fig. 1: Excitation function of proton induced reaction of ^{28}Si with shell correction. It clearly shows that (*p*, *p*) reaction is the prominent reaction in the interaction, with peak cross-section of 884.42mb, with a corresponding energy of 15MeV. The threshold energy of (*p*, *p*) reaction is 1.09 MeV, with cross section of 2.70mb.

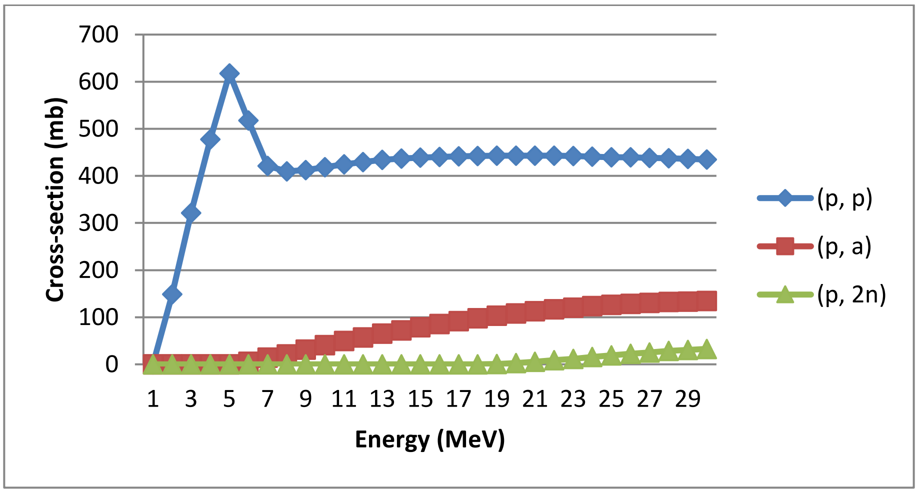

Fig. 2: Excitation function of proton induced reaction of ^{28}Si Without Shell Correction. It shows that (*p*, *p*) reaction is the prominent reaction in the interaction, with peak cross-section of 887.86mb, with a

corresponding energy of 15MeV. The threshold energy of (*p, p*) reaction is 1.09 MeV, with cross section of 2.90mb. With comparison in terms of the shell correction, it shows that cross section is higher when the shell correction is not considered at the given energy range.

Table 2: Cross section for Proton induced reactions of Si29 with energy range of 1-30MeV from EXIFON code.

Element	Energy (MeV)	Cross Section with Shell Correction (mb)			Cross Section Without Shell Correction (mb)		
		(p, p)	**(p, a)**	**(p, 2n)**	**(p, p)**	**(p, a)**	**(p, 2n)**
	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	152.60	0.00	0.00	154.90	0.00	0.00
	3.00	309.72	0.00	0.00	309.98	0.00	0.00
	4.00	460.39	0.00	0.00	460.48	0.00	0.00
	5.00	599.33	0.00	0.00	599.39	0.00	0.00
	6.00	692.69	0.00	0.00	692.74	0.00	0.00
	7.00	755.21	0.00	0.00	754.69	0.00	0.00
	8.00	785.69	0.21	0.00	785.01	0.18	0.00
	9.00	792.57	6.78	0.00	795.23	5.80	0.00
	10.00	786.60	21.36	0.00	791.59	18.16	0.00
	11.00	772.11	41.03	0.00	779.02	34.66	0.00
	12.00	756.53	58.79	0.00	764.50	49.81	0.00
	13.00	737.64	78.22	0.00	746.74	66.25	0.00
	14.00	720.09	94.78	0.00	729.61	80.44	0.00
	15.00	703.87	108.76	0.00	713.24	92.66	0.00
Si29	16.00	688.88	120.60	0.00	697.59	103.31	0.00
	17.00	674.67	130.84	0.00	682.57	112.72	0.00
	18.00	661.45	139.45	0.00	668.31	120.88	0.00
	19.00	648.52	147.32	0.00	654.38	128.42	0.00
	20.00	636.16	154.19	0.00	640.98	135.15	0.00
	21.00	624.31	160.20	0.00	628.06	141.19	0.00
	22.00	612.91	165.45	0.00	615.59	146.59	0.00

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	23.00	601.92	169.99	0.00	604.48	150.93	0.00
	24.00	591.29	173.86	0.00	593.29	154.89	0.00
	25.00	581.01	177.19	0.00	582.59	158.30	0.00
	26.00	572.32	179.29	0.00	572.39	161.15	0.00
	27.00	563.23	181.30	0.00	562.68	163.47	0.00
	28.00	554.55	182.79	0.00	553.41	165.33	0.00
	29.00	546.23	183.83	0.00	544.54	166.75	0.00
	30.00	538.24	184.44	0.00	536.04	167.78	0.00

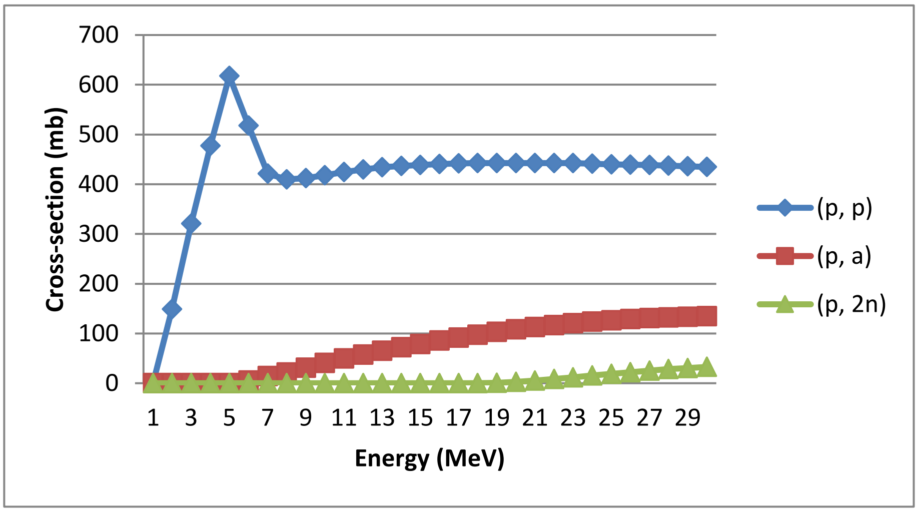

Fig. 3: Excitation function of proton induced reaction of ^{29}Si with shell correction. It shows that (*p*, *p*) reaction is the prominent reaction in the interaction, with peak cross-section of 792.57mb, with a corresponding energy of 9MeV. The threshold energy of (*p*, *p*) reaction is 1.09 MeV, with cross section of 0.5mb.

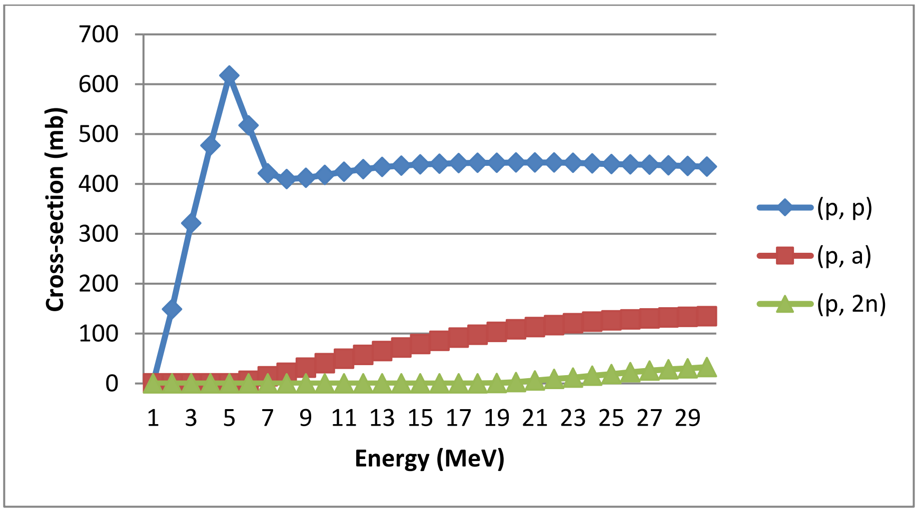

Fig. 4: Excitation function of proton induced reaction of ^{29}Si without shell correction. It shows that (*p*, *p*) reaction is the prominent reaction in the interaction, with peak cross-section of 795.23mb, with a corresponding energy of 9MeV. The threshold energy of (*p*, *p*) reaction is 1.09 MeV, with cross section of 0.5mb. With comparison in terms of the shell correction, it shows that cross section is higher when the shell correction is not considered at the given energy range.

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Table 3: Cross section for Proton induced reactions of Si30 with energy range of 1-30MeV from EXIFON code.

Element	Energy (Mev)	Cross Section with Shell Correction (mb)			Cross Section Without Shell Correction (mb)		
		(p, p)	(p, a)	(p, 2n)	(p, p)	(p, a)	(p, 2n)
Si30	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	143.49	0.00	0.00	148.80	0.00	0.00
	3.00	320.41	0.00	0.00	321.14	0.00	0.00
	4.00	477.02	0.00	0.00	477.28	0.00	0.00
	5.00	617.53	0.00	0.00	617.69	0.00	0.00
	6.00	504.91	5.97	0.00	517.59	5.36	0.00
	7.00	408.11	15.48	0.00	421.37	14.31	0.00
	8.00	395.54	22.79	0.00	409.89	21.25	0.00
	9.00	396.19	33.54	0.00	412.40	31.36	0.00
	10.00	400.17	43.63	0.00	418.36	40.81	0.00
	11.00	404.35	52.83	0.00	424.45	49.40	0.00
	12.00	407.75	61.39	0.00	429.66	57.36	0.00
	13.00	410.35	69.78	0.00	433.89	65.13	0.00
	14.00	411.99	77.20	0.00	436.86	72.04	0.00
	15.00	413.00	84.63	0.00	438.94	78.96	0.00
	16.00	413.59	91.68	0.00	440.35	85.56	0.00
	17.00	414.18	98.23	0.00	441.75	91.76	0.00
	18.00	414.42	104.54	0.08	442.45	97.66	0.08
	19.00	414.38	110.47	0.99	442.70	103.28	0.91
	20.00	414.54	115.79	3.02	442.79	108.19	2.84
	21.00	414.46	120.38	5.92	442.84	112.77	5.56
	22.00	414.62	124.63	9.33	442.82	116.87	8.81
	23.00	414.39	128.36	12.19	442.33	120.50	11.61
	24.00	413.55	131.63	15.98	441.21	123.67	15.28
	25.00	412.55	134.52	19.66	439.87	126.49	18.88
	26.00	411.73	136.88	23.10	439.52	128.61	22.24
	27.00	411.52	138.66	26.28	438.38	130.54	25.44
	28.00	410.84	140.23	29.08	437.23	132.12	28.25

	29.00	410.17	141.46	31.27	436.05	133.40	30.53
	30.00	409.49	142.41	33.47	434.84	134.41	32.77

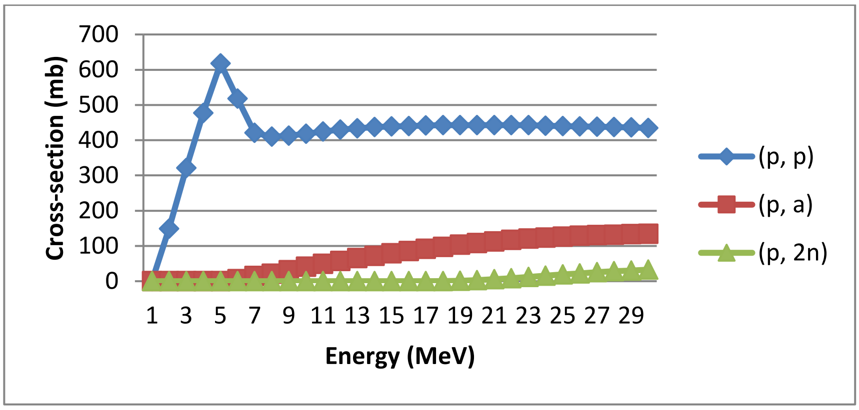

Fig. 5: Excitation function of Proton induced reactions of ^{30}Si with shell correction. It's clearly shows that (*p*, *p*) reaction has the prominent reaction in the interaction, with peak cross-section of 414.62mb, with a corresponding energy of 22MeV. The threshold energy of (*p*, *p*) reaction is 1.09 MeV, with cross section of 3.0mb.

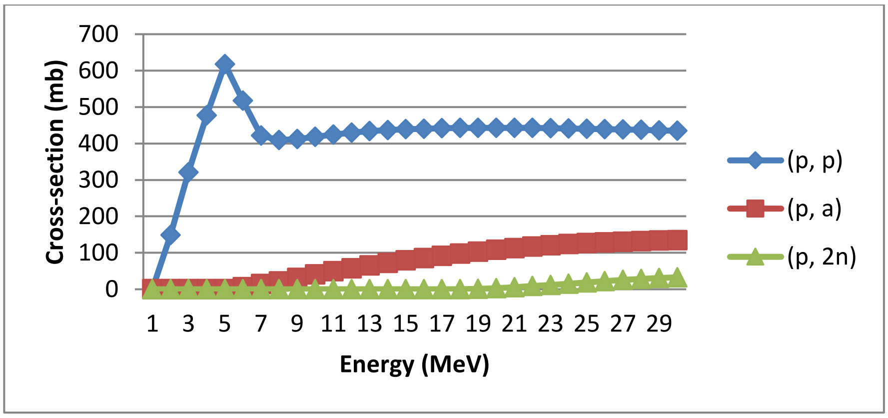

Fig. 6: Excitation function of Proton induced reactions of ^{30}Si without shell correction. It shows that (*p*, *p*) reaction has the prominent reaction in the interaction, with peak cross-section of 442.84mb, with a corresponding energy of 21MeV. The threshold energy of (*p*, *p*) reaction is 1.09 MeV, with cross section of 3.4mb. With comparison in terms of the shell correction, it shows that cross section is higher when the shell correction is not considered at the given energy range.

BENCHMARKING AND VALIDATION OF RESULTS

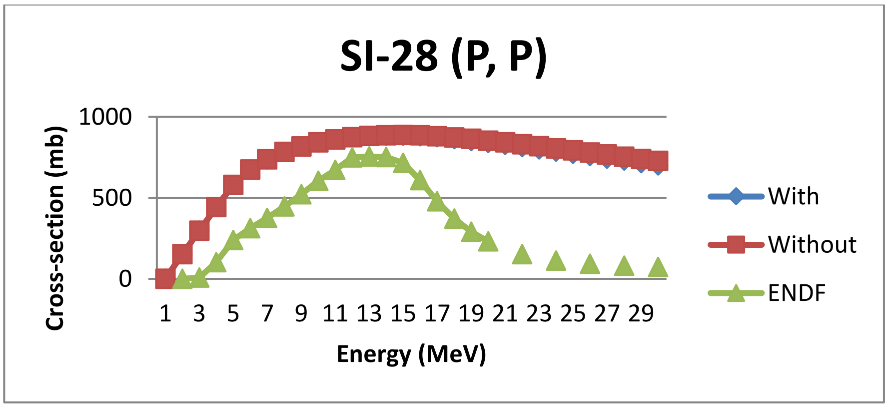

Fig. 7: Cross section against energy for the $^{28}Si(p,\ p)\,^{28}Si$ reaction. The $^{28}Si(p,\ p)\,^{28}Si$ reaction cross-section starts to show values at 2 MeV. Evaluated data are available up to 30 MeV. There are no experimental

results for the $^{28}Si(p,\ p)\ ^{28}Si$ reaction cross-section in the EXFOR database. The calculations from EXIFON over predict the evaluated data.

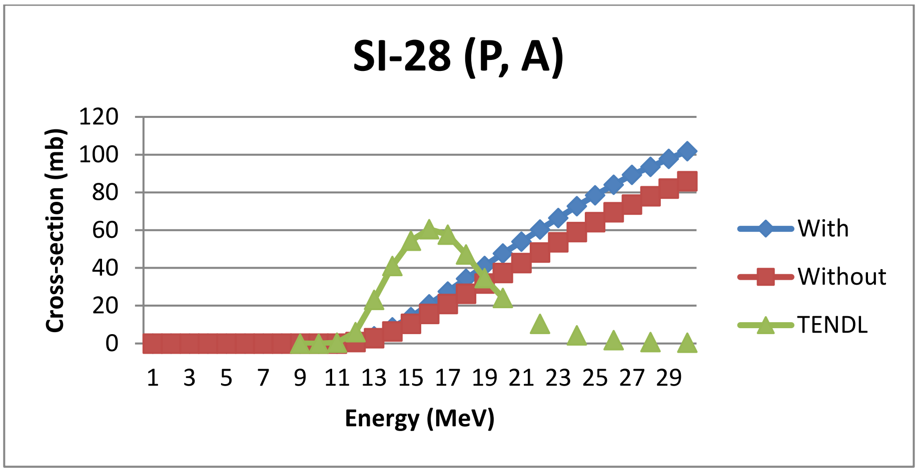

Fig. 8: Cross section against energy for the $^{28}Si\ (p,\ a)\ ^{25}Al$ reaction. The $^{28}Si\ (p,\ a)\ ^{25}Al$ reaction cross-section starts to generate values at 12 MeV. Evaluated data are available up to 30 MeV. There are no experimental results for the $^{28}Si\ (p,\ a)\ ^{25}Al$ reaction cross-section in the EXFOR database, EXIFON code calculation of 19MeV is in good agreement with evaluated nuclear data. Theoretical results over predict the cross section from evaluated library.

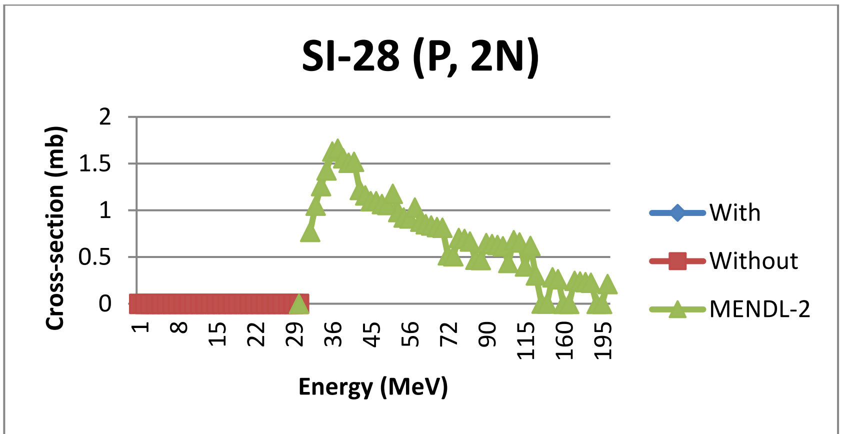

Fig. 9: Cross section against energy for the $^{28}Si\ (p,\ 2n)\ ^{27}P$ reaction. The $^{28}Si\ (p,\ 2n)\ ^{27}P$ reaction cross-section does not generate values up to 20 MeV. Evaluated data are available up to 200 MeV. There are no experimental results for the $^{28}Si\ (p,\ 2n)\ ^{27}P$ reaction cross-section in the EXFOR database. The calculations from EXIFON under predict the evaluated data.

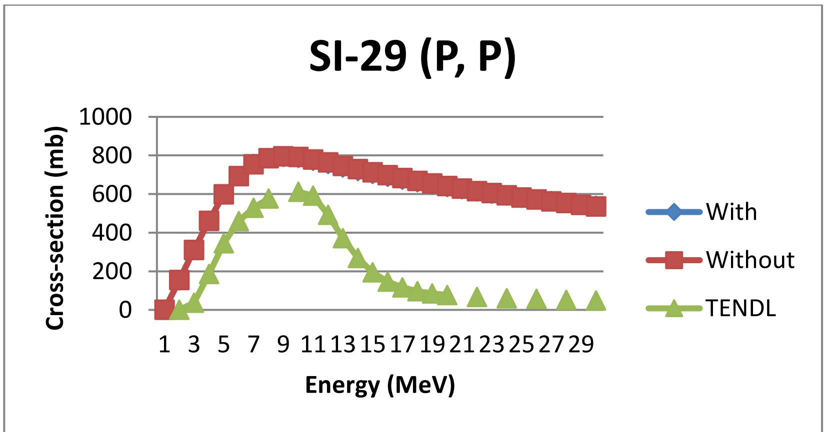

Fig. 10: Cross section against energy for the $^{29}Si\ (p,\ p)\ ^{29}Si$ reaction. The $^{29}Si\ (p,\ p)\ ^{29}Si$ reaction cross-section starts to show values at 2 MeV. Evaluated data are available up to 30 MeV. There are no experimental

results for the $^{29}Si\ (p,\ p)\ ^{29}Si$ reaction cross-section in the EXFOR database. The calculations from EXIFON over predict the evaluated data.

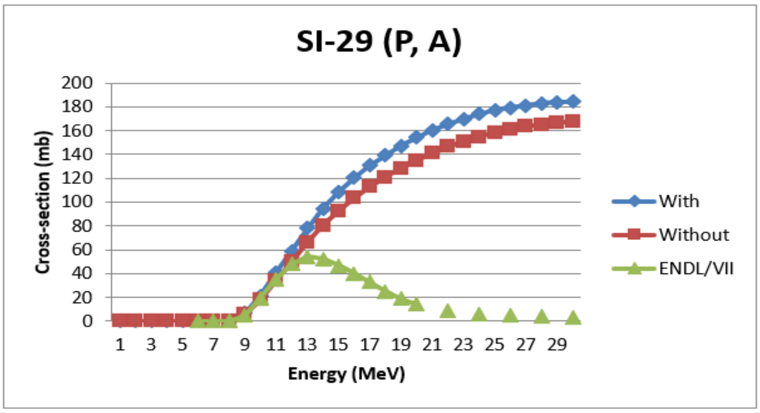

Fig. 11: Cross section against energy for the $^{29}Si\ (p,\ a)\ ^{26}Al$ reaction. The $^{29}Si\ (p,\ a)\ ^{26}Al$ reaction cross-section starts to generate values at 8 MeV. Evaluated data are available up to 30 MeV. There are no experimental results for the $^{29}Si\ (p,\ a)\ ^{26}Al$ reaction cross-section in the EXFOR database. Fig. 11 shows that results of the EXIFON code calculation are in good agreement with evaluated data from 6 – 12 MeV energy regions. From 13 – 30 MeV, theoretical results over predict cross-sections from evaluated library.

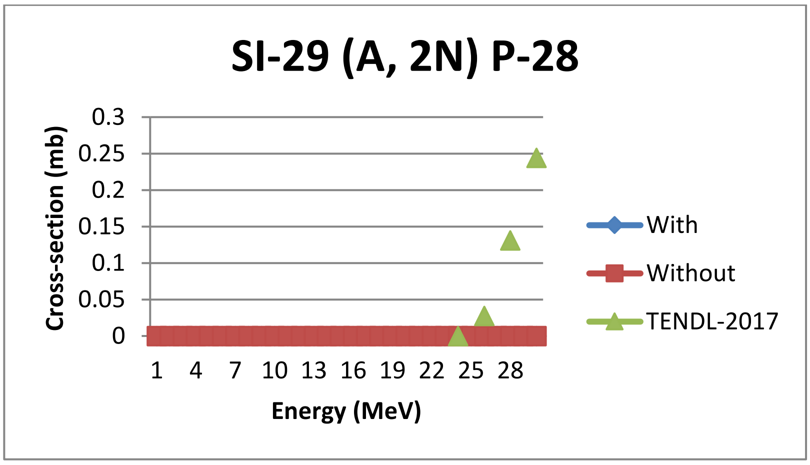

Fig. 12: Cross section against energy for the $^{29}Si\ (p,\ 2n)\ ^{28}P$ reaction. The $^{29}Si\ (p,\ 2n)\ ^{28}P$ reaction cross-section does not generate values up to 20 MeV. Evaluated data are available up to 30 MeV. There are no experimental results for the $^{29}Si\ (p,\ 2n)\ ^{28}P$ reaction cross-section in the EXFOR database. The calculations from EXIFON under predict the evaluated data.

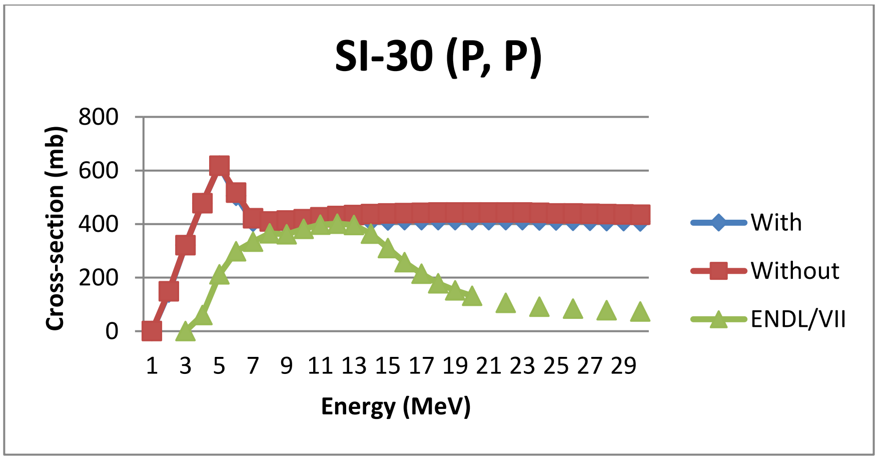

Fig. 13: Cross section against energy for the $^{30}Si\ (p,\ p)\ ^{30}Si$ reaction. The $^{30}Si\ (p,\ p)\ ^{30}Si$ reaction cross-section starts to show values at 2 MeV. Evaluated data are available up to 30 MeV. There are no experimental

results for the $^{30}Si\ (p,\ p)\ ^{30}Si$ reaction cross-section in the EXFOR database. Fig. 13 shows that results of the EXIFON code calculation are in fair agreement with evaluated data From 11 – 13 MeV energy regions. From 14 – 30 MeV, calculations from EXIFON over predict cross-sections from evaluated library.

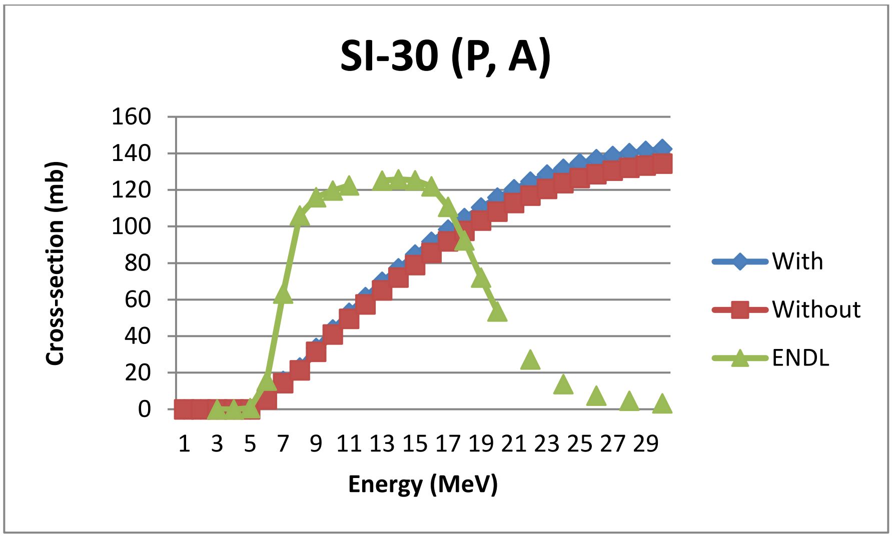

Fig. 14: Cross section against energy for the $^{30}Si\ (p,\ a)\ ^{27}Al$ reaction. The $^{30}Si\ (p,\ a)\ ^{27}Al$ reaction cross-section starts to generate values at 5 MeV. Evaluated data are available up to 30 MeV. There are no experimental results for the $^{30}Si\ (p,\ a)\ ^{27}Al$ reaction cross-section in the EXFOR database. The calculations from EXIFON between 6-18 MeV under predict the evaluated data.

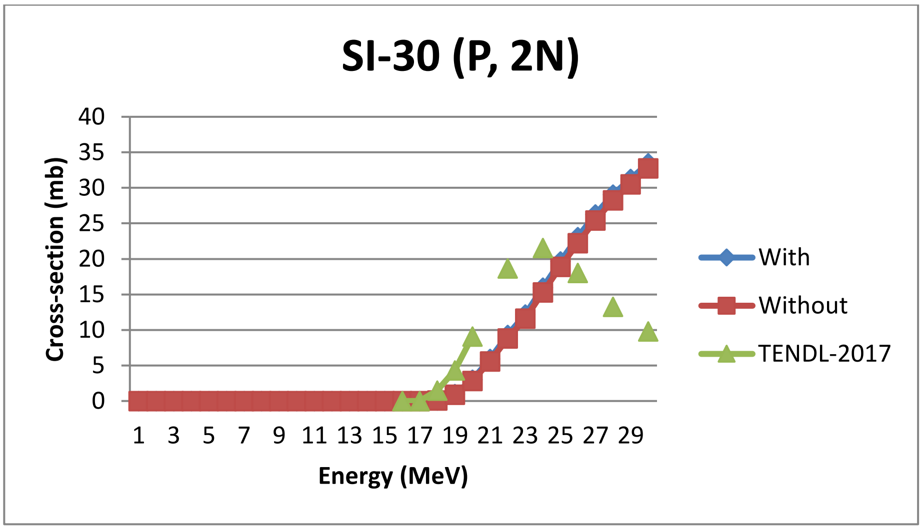

Fig. 15: Cross section against energy for the $^{30}Si\ (p,\ 2n)\ ^{29}P$ reaction. The $^{30}Si\ (p,\ 2n)\ ^{29}P$ reaction cross-section does not generate values up to 20 MeV. Evaluated data are available from 16.8831 to 30 MeV. There are no experimental results for the $^{30}Si\ (p,\ 2n)\ ^{29}P$ reaction cross-section in the EXFOR database. The calculations from EXIFON code is in fair agreement between 16 and 17 MeV with evaluated data. From 18 – 30 MeV, calculations from EXIFON under predict cross-sections from evaluated library.

CONCLUSION

The nuclear model reaction cross-section and excitation function for proton-induced reactions of silicon isotopes were calculated using the statistical multistep compound reactions (SMD/SMC model) and statistical multistep direct reactions. Additionally, calculated values have been benchmarked, compared, and validated against data from the nuclear data bank of the International Atomic Energy Agency (IAEA) and assessed database (ENDF). When no experimental data were available, the cross section data may be predicted by the theoretical model code (EXIFON). Nuclear model calculations of cross-section for proton induced reactions in silicon isotopes where performed using the EXIFON 2.0 code, the code which was accounted for the charge

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particle interaction in the energy region of 1-30 MeV. Due to the lack of measured cross-sections beyond 30 MeV, more experimental (ENDF) data are needed in order to further test the reliability of the theoretical calculations. Another advantage of the EXIFON code is that it was able to provide information of most of the cross section data for the silicon isotopes.

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