Excited states of ^{26}Al studied via the reaction ^{27}Al(d,t)

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Outline

- Introduction
- Previous works & Motivation
- Present work
- Experiment
- Results
- Summary

Transfer Reactions

In transfer reactions, modification in nuclear composition occurs.
Pick-up ,stripping reactions.

- Pick - up Reaction : nucleon transfer from target to projectile.

  Exp : (d, t) type of reactions.

- Stripping Reaction : nucleon transfer from projectile to target.

  Exp : (d , p) is a stripping type of reactions.

Importance of single nucleon transfer reaction

- Single nucleon transfer reaction enables us to determine many nuclear properties of nuclei like excitation energy of individual excited state, orbital and total angular momentum and also we can calculate spectroscopic factors. We can test the prediction of the shell model for the structure of nuclei.

Let us consider a transfer reaction as ; $\quad a + A(B + x) \rightarrow b(a + x) + B$

Example: $d + {}^{27}Al \rightarrow {}^{3}H + {}^{26}Al$

The transition amplitude for the above process may be expressed as:

$$T_{DWBA} = \int \underbrace{\chi^{(-)}(\vec{k}_b,\vec{r}_b)^* \langle \psi_B \psi_b | V | \psi_A \psi_a \rangle}_{} \chi^{(+)}(\vec{k}_a,\vec{r}_a) d\vec{r}_a d\vec{r}_b$$

It includes the target and projectile overlap function: $\boldsymbol{< \psi_b \mid \psi_a > \; and < \psi_B \mid \psi_A >}$. The measurement of the overlap of this kind is the spectroscopic factors.

Spectroscopic Factors : It is a fundamental property of nuclides, it should be independent of incident energies or involved reactions.

Mathematically, $\quad \left(\frac{d\sigma}{d\Omega}\right)_{EXP} = S_{exp.} \left(\frac{d\sigma}{d\Omega}\right)_{Th.}$

- If $S_{exp.} \approx S_{th}$, then our experiment is in good agreement with theory.
- If $S_{exp} \gg S_{th}$ or $S_{exp.} \ll S_{th}$, then either theory needs modification or experimental analysis needs revised otherwise any other reason.

Previous Works and Motivation

- ^{26}Al is the first cosmic radioactivity ever detected.

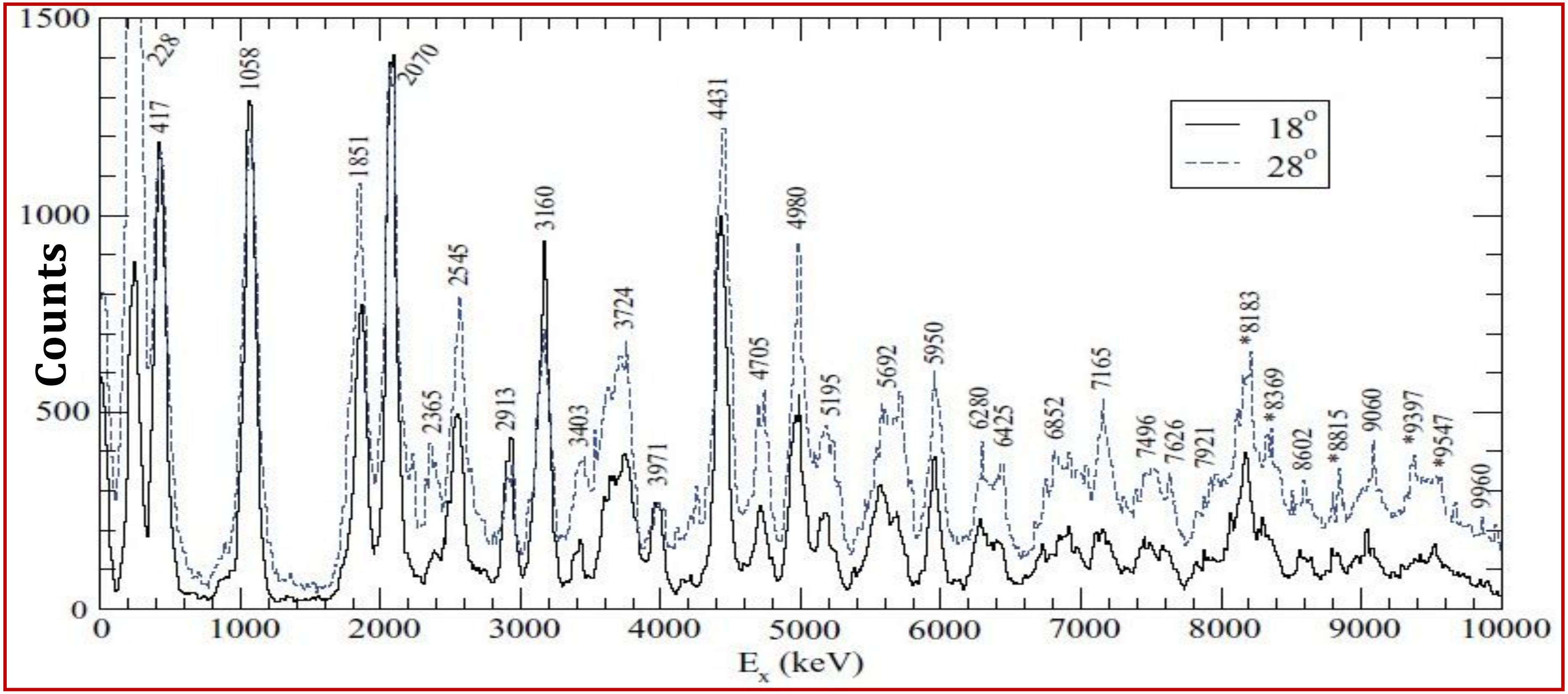
  Nikos Prantzos et al ., Phys. Rep. 267,1-69(1996).

- Radioactive ^{26}Al from massive stars in the Galaxy.

  Diehl et al ., Nature(London) 439,45(2006).

- Particle transfer reactions as ^{28}Si(p,^{3}He), ^{28}Si(d,α) and ^{24}Mg(^{3}He,p), ^{27}Al(p,d), ^{27}Al(^{3}He,α) , ^{27}Al(p,d) , ^{27}Al(d,t), etc.
- Five new Excited states have been identified.

  Chipps et al ., Phys. Rev. C 86, 14329(2012)



Present work

Study of one neutron transfer reaction ^{27}Al (d , t) and
to extract the spectroscopic factors for different excited states of ^{26}Al.

Experimental Details

Projectile : d

Targets : ^{27}Al

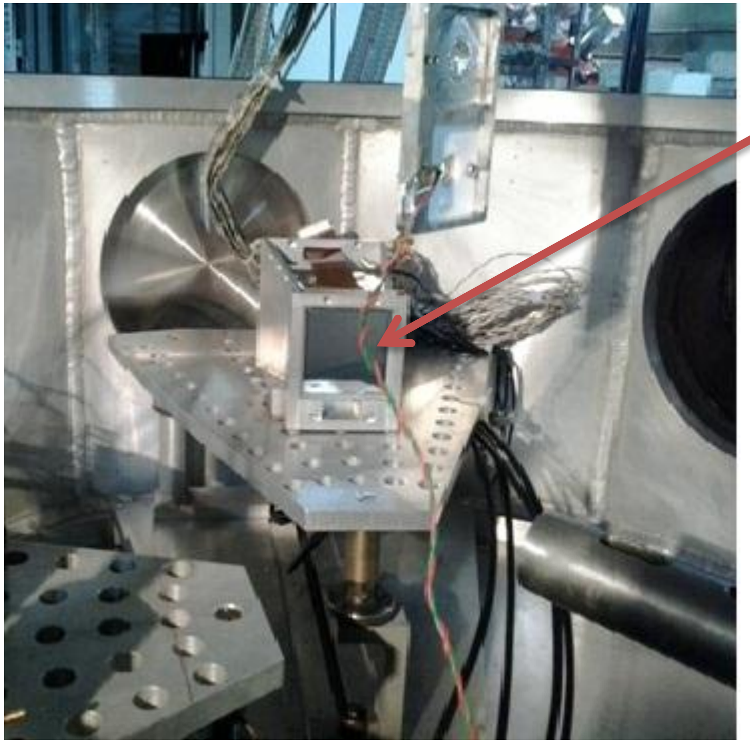
Energy : 25 MeV

Objective: To study 1n transfer reaction (d, ^{3}H) on ^{27}Al.

Experimental Setup

Experiment was performed at VECC Kolkata , India using 25 MeV deuteron beam .

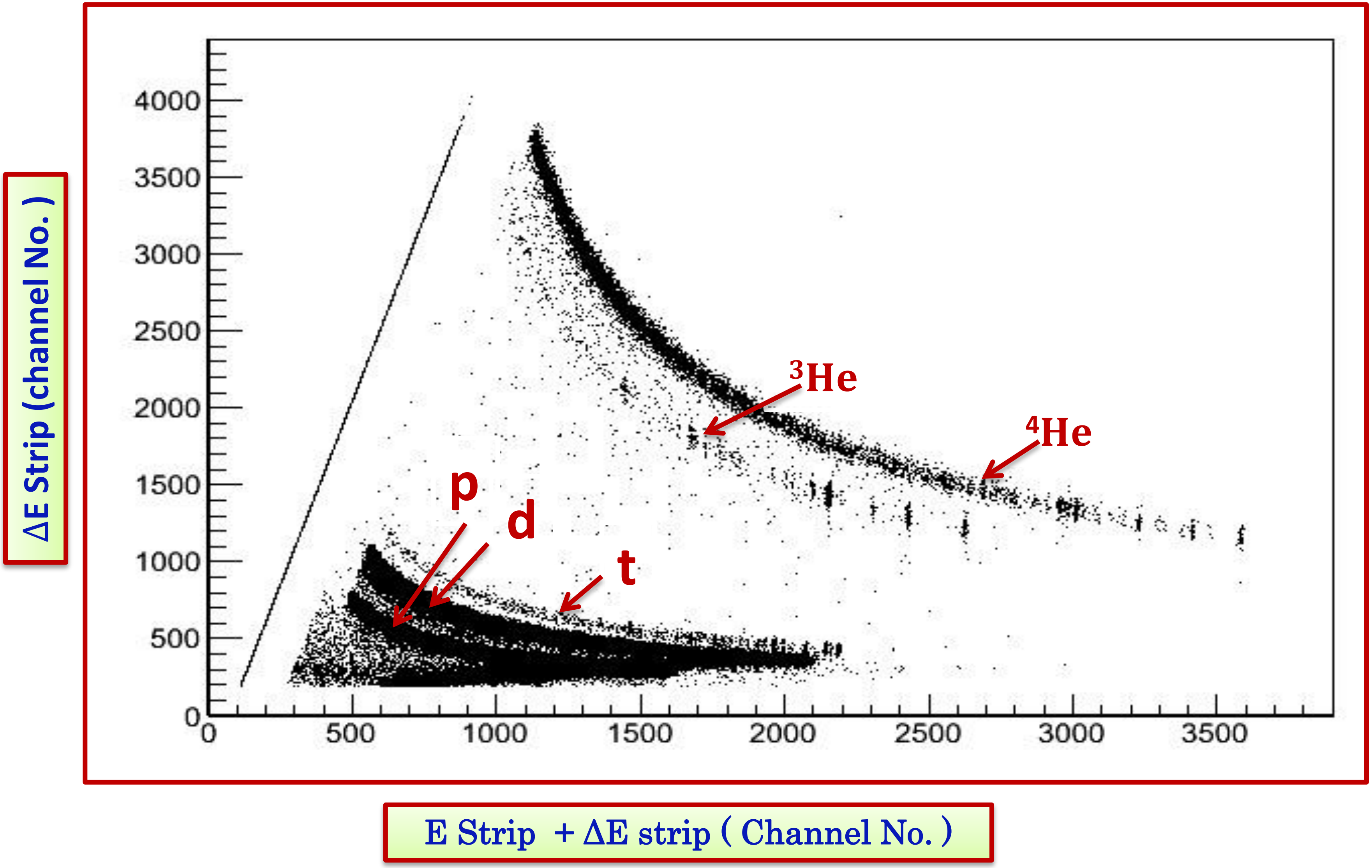
Particle identification by Si –strip detector(ΔE) – Si-strip detector(E) – 2CsI(Tl) detector telescope for d + ^{27}Al Experiment

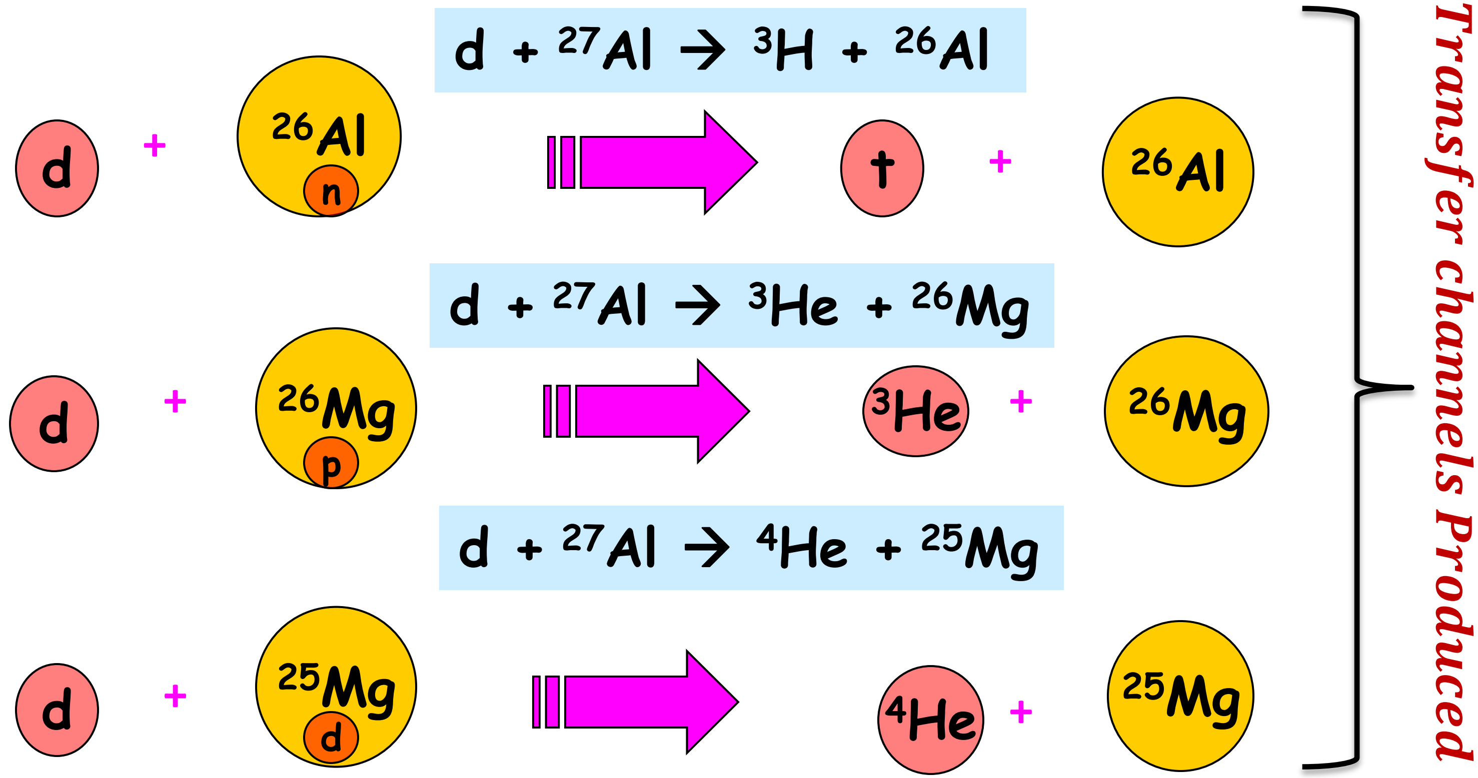


- T1 Strip detector telescope – Si strip det. ΔE(55µm)+Si strip det E strip(1030 µm) + 2 CsI(Tl) (6 cm)

Target: ^{27}Al (90µg/cm^2) &
Distance of T1 from target 19.6 cm
Angular resolution for T1 0.9˚,
Angular range covered 16° to 40°.

Typical two Dimensional spectrum obtained by Si-strip(ΔE)–Si-strip(E) telescope for d + ^{27}Al Experiment for 25 MeV deuteron beam





Optical model potential parameters were extracted using ECIS94 Optical Model Code from the elastic scattering cross-section.

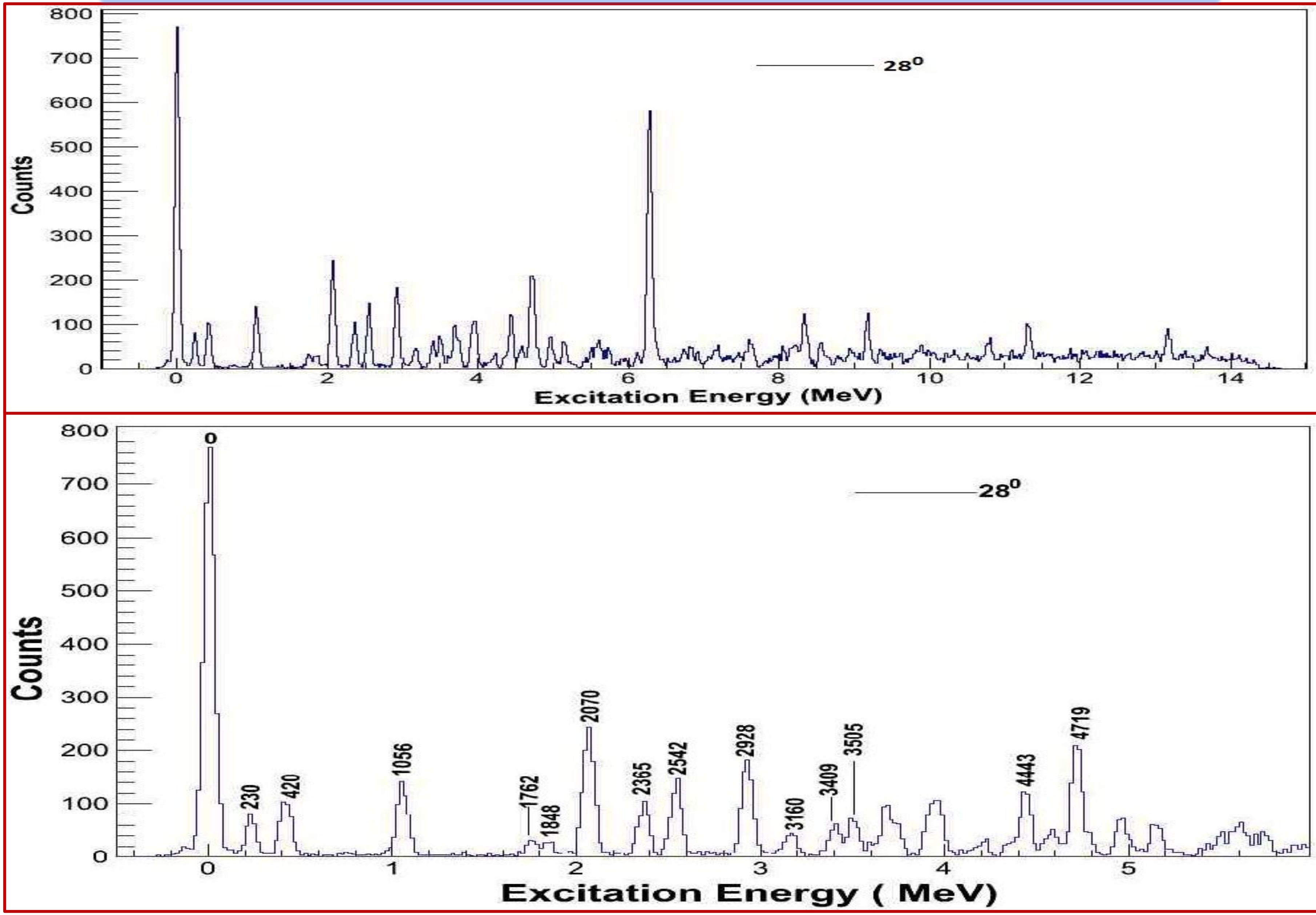
Ref : J. Raynal Notes on ECIS94, NEA 0850/16

And

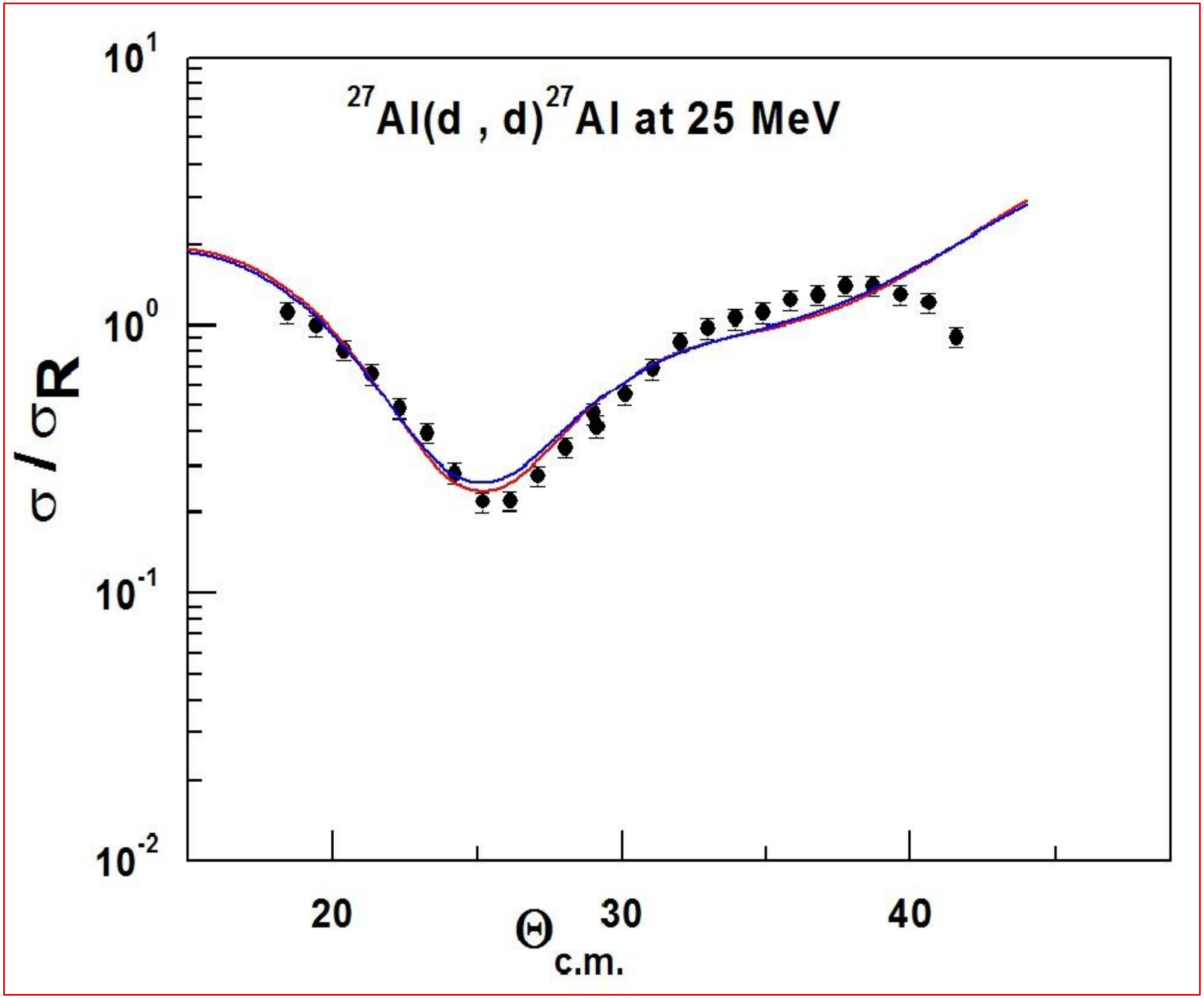
Cross-section for different excited states were analyzed using zero-range DWUCK4 code.

Ref : http://spot.colorado.edu/~kunz/DWBA.html

Excitation energy spectrum of ^{26}Al at $\theta_{lab} = 28°$



Angular Distribution of Elastic Scattering



Extracted Optical model potential parameters using ECIS94 code

OMP Parameters	d + ^{27}Al Set A	Set B	Set C	^{3}H + ^{26}Al Set A1	Set B1
V (MeV)	89.209	90.301	88.095	161.91	172.0
r_o (fm)	1.061	1.055	1.055	1.20	1.140
a_o(fm)	0.701	0.675	0.780	0.72	0.710
W_v(MeV)				39.99	17.52
r_v(fm)	1.360	1.400	1.300	1.400	1.670
a_v(fm)	0.850	0.850	0.650	0.840	0.780
W_D(MeV)	2.25	2.407	3.524		
V_{ls}(MeV)	9	9	9	2.50	
r_{ls}(fm)	1.061	1.055	1.055	1.20	
a_{ls}(fm)	0.801	0.780	0.780	0.72	
Rc(fm)	1.25	1.25	1.25	1.30	1.30

Relation of experimental cross section with DWUCK 4 and DWUCK 5

$$\left(\frac{d\sigma}{d\Omega}\right)_{EXP} = N \, \frac{C^2S}{2J+1} \left(\frac{d\sigma}{d\Omega}\right)_{DWUCK4}$$

Where, The value N for (d , t) reaction is 3.33 and J is total angular momentum of the orbit from which neutron is picked up. C is the isotopic Clebsch-Gordan coefficient and S is the spectroscopic factor.

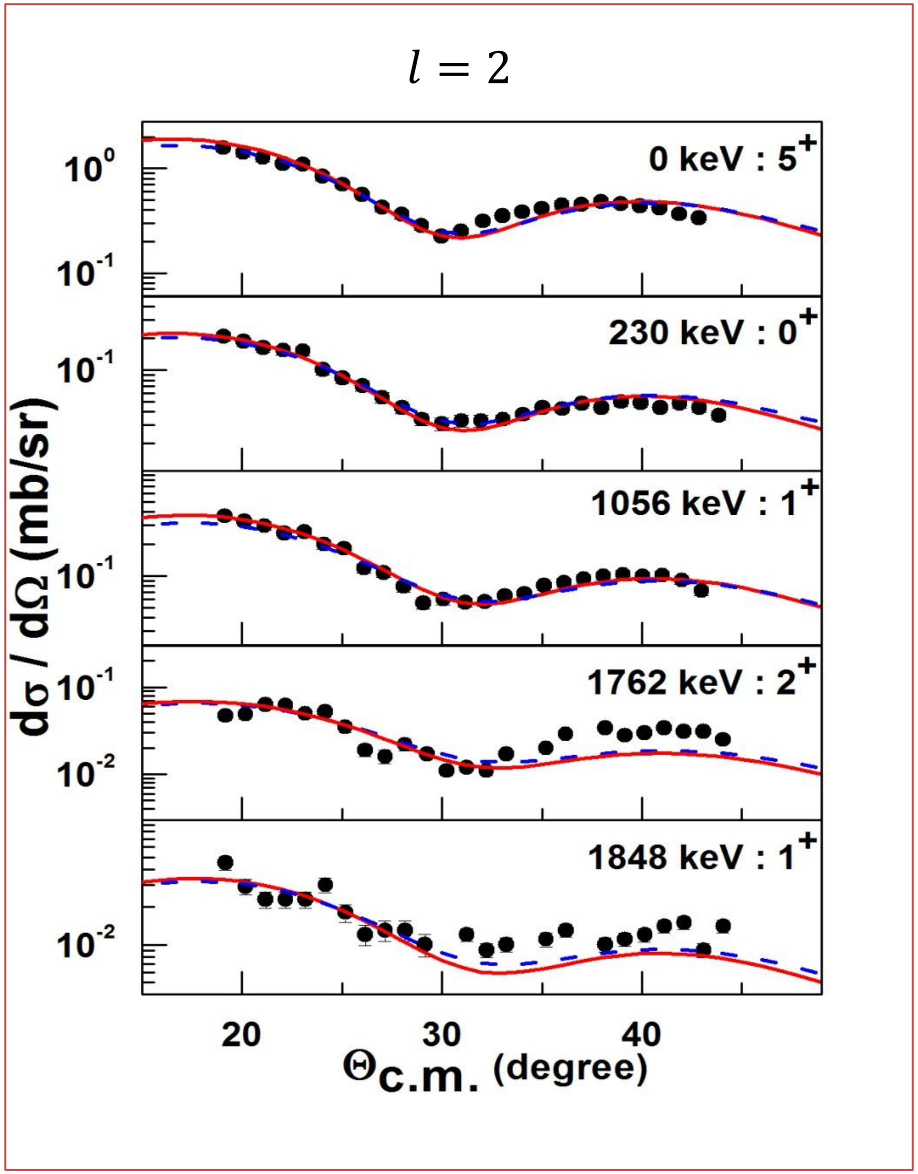
$$\left(\frac{d\sigma}{d\Omega}\right)_{EXP} = gG \left(\frac{d\sigma}{d\Omega}\right)_{DWUCK5}$$

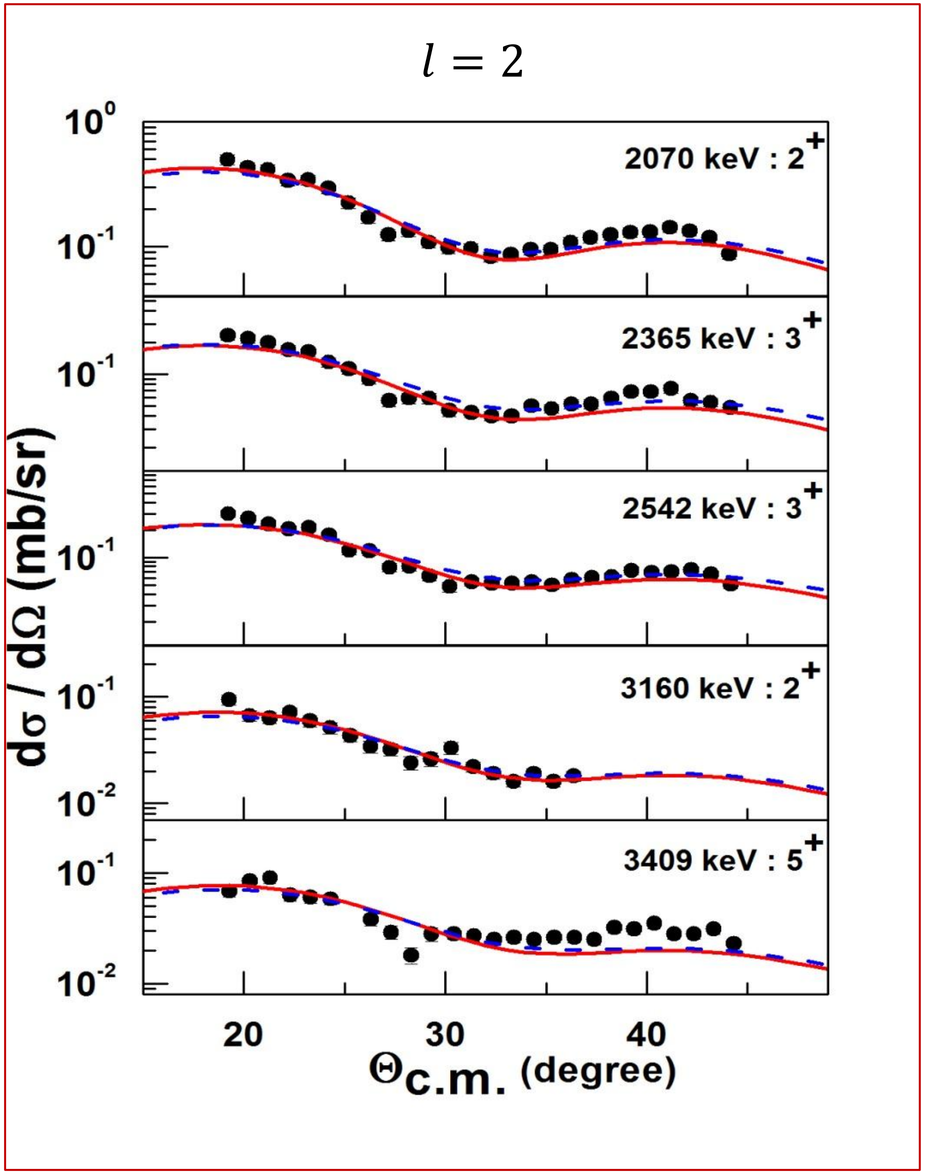
where g = light particle spectroscopic factor and its value for (d , t) reaction is 1.5 and G is measured spectroscopic strength.

$$G = C^2S$$

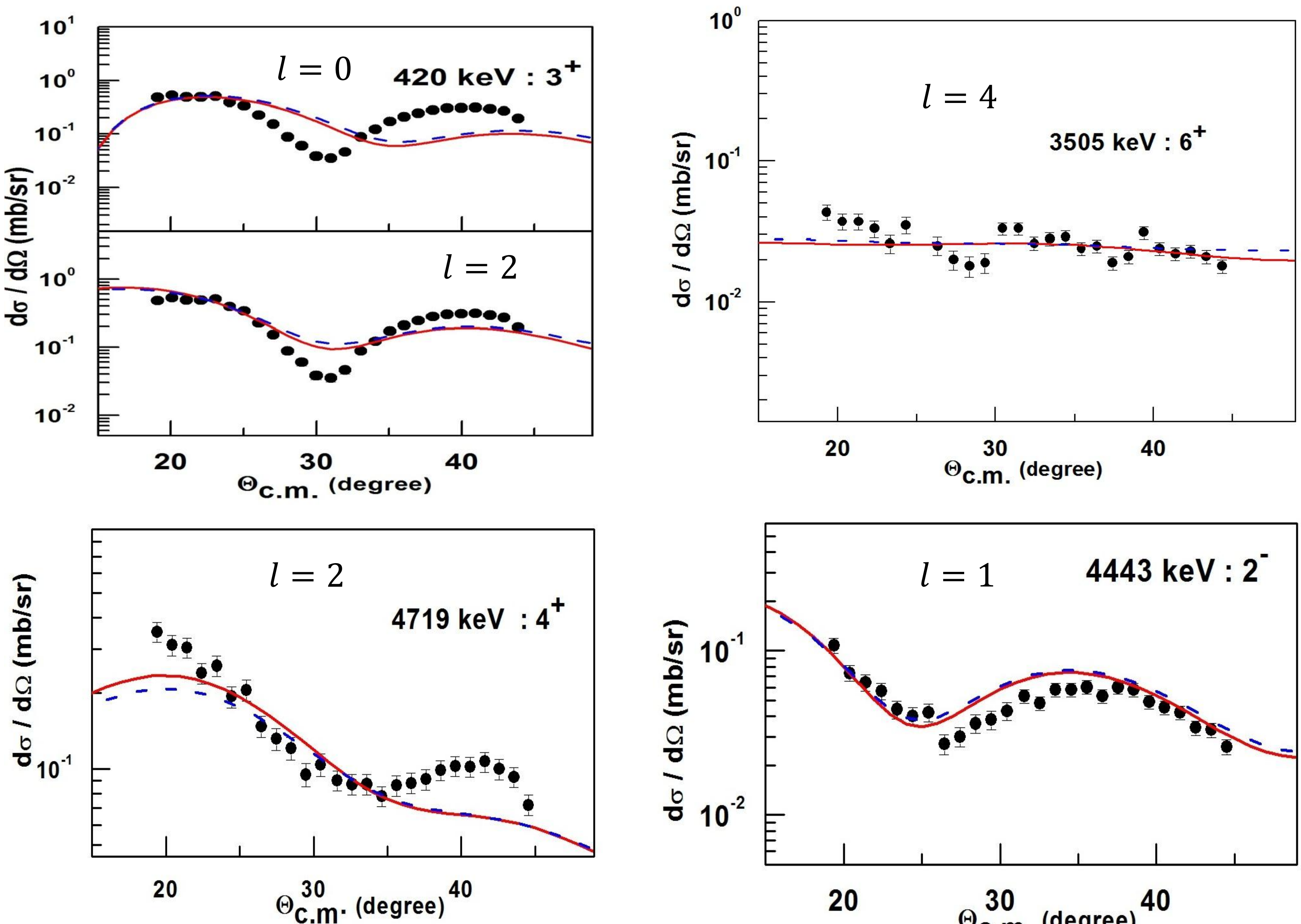
Angular Distribution of Excited States of ^{26}Al

Phys. Rev. C 91, 054611 (2015).





Angular Distribution of Excited States of ^{26}Al *Phys. Rev. C 91, 054611 (2015).*



Extracted Values of Spectroscopic Factors Using ZR-DWBA

Ex (keV)	$C^2S^{(a)}$	Relative $C^2S^{(a)}$	(P,d)[1] Relative	(p,d)[2] Relative	(3He,α)[3] Relative	(d,t)[4] Relative
0	0.73±0.21	1	1	1	1	1
230	0.09 ± 0.03	0.12	0.15	0.14	0.14	0.15
420 (l=2)	0.32 ± 0.07	0.44		0.05		
420(l=0)	0.07 ± 0.03	0.09	0.18	0.15	0.12	0.12
1056	0.17 ± 0.05	0.24	0.24	0.31	0.31	0.29
1762	0.038±0.006	0.05	0.07	0.02	0.02	
1848	0.019±0.004	0.03	0.05	0.016	0.02	
2070	0.26 ± 0.06	0.35		0.52	0.50	
2365	0.13 ± 0.02	0.18	0.28	0.23	0.26	

[a] Present Experiment

References:

1: Nucl. Phys. A204, ,609 (1973)
2: Nucl. Phys. A263, ,293 (1976)
3: PRC 8 , 670 (1973)
4: Nucl. Phys. A107, ,581 (1968)

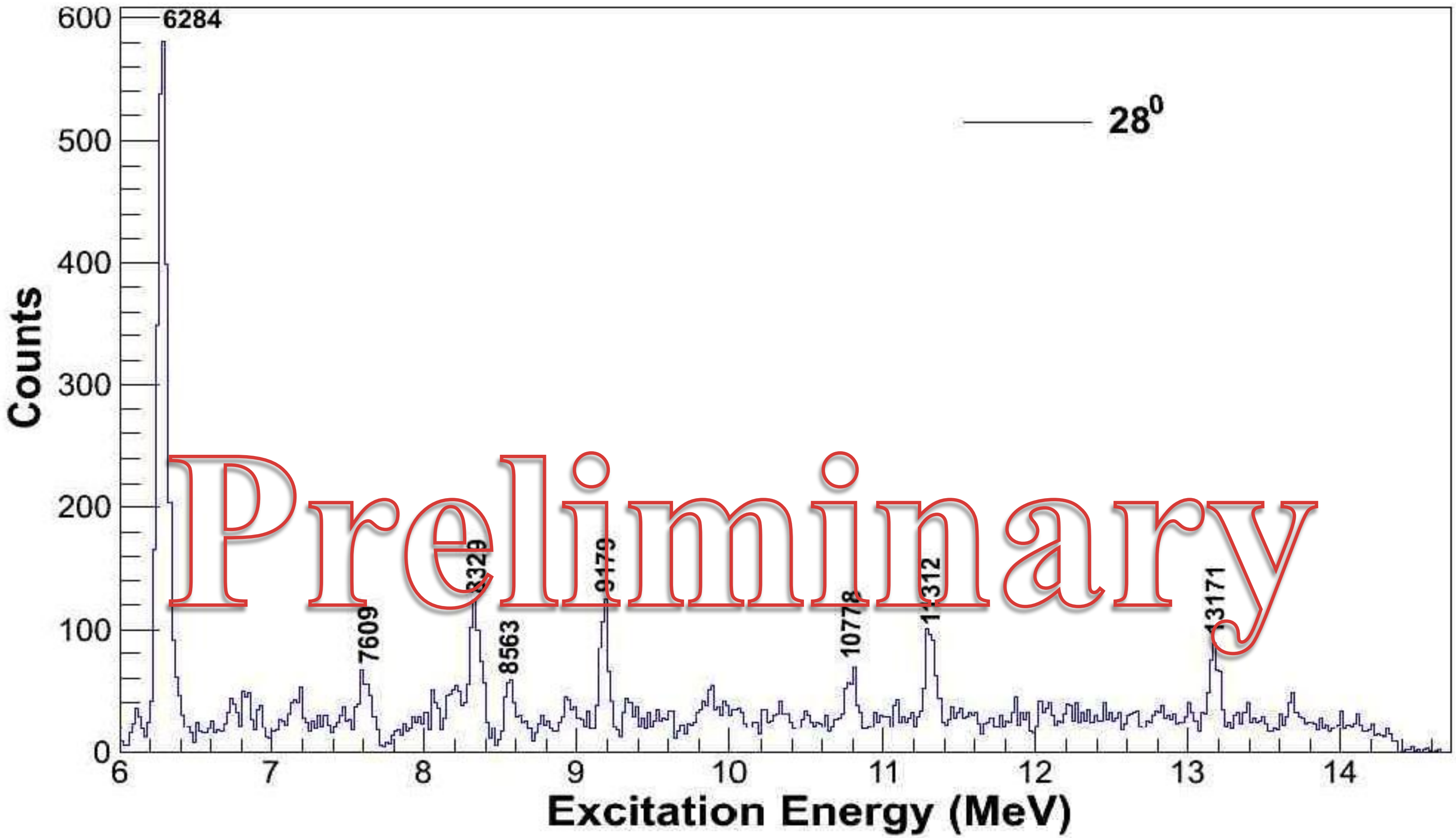
Extracted Values of Spectroscopic Factors Using ZR-DWBA

Ex (keV)	$C^2S^{(a)}$	Relative $C^2S^{(a)}$	(P,d)[1] Relative	(p,d)[2] Relative	(3He,α)[3] Relative	(d,t)[4] Relative
2542	0.16 ± 0.03	0.22	0.28	0.30	0.30	
3160	0.06 ± 0.01	0.08	0.12	0.10	0.10	
3409	0.06 ± 0.01	0.09	0.19	0.09	0.08	
3505	0.06 ± 0.03	0.08		0.04		
4443	0.23 ± 0.04	0.32		0.02	0.02	
4719	0.27 ± 0.08	0.37	1	0.71	0.86	

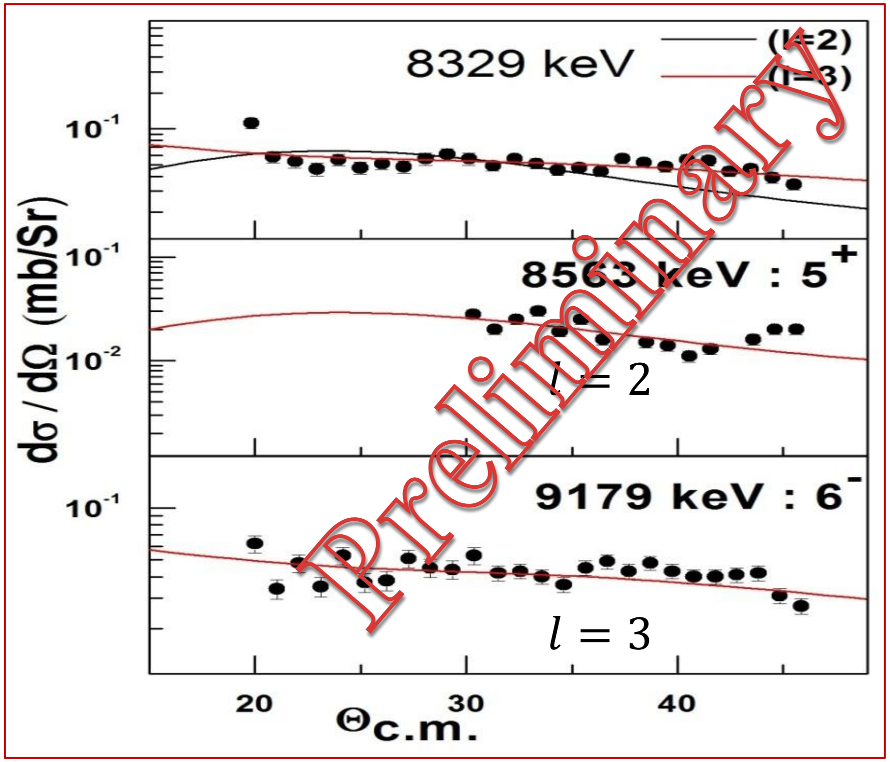
Published in:

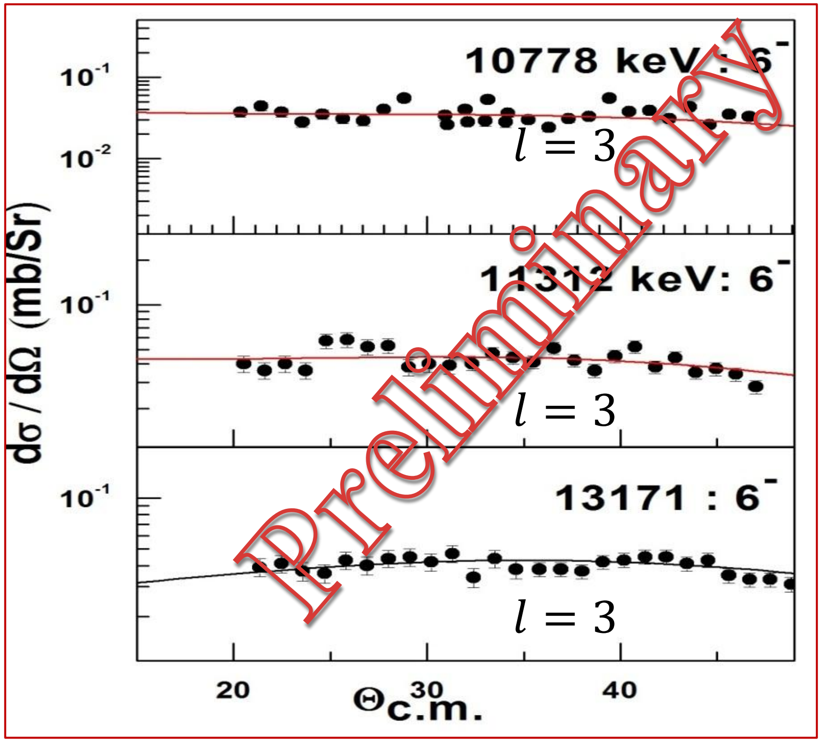
- Vishal Srivastava *et al.*, Phys. Rev. C 91, 054611 (2015).
- Vishal Srivastava *et al.*, EPJ Web Conf. 86, 00055 (2015)

Higher Excited States of ^{26}Al



Extracted Values of Spectroscopic Factors Using ZR-DWBA





Ex (keV)	ln	C^2S
8329	2	0.21±0.03
	3	0.15±0.05
8563	2	0.11±0.03
9179	3	0.11±0.04

Ex (keV)	l	C^2S
10778	3	0.12±0.04
11312	3	0.17±0.06
13171	3	0.34±0.15

Preliminary

Preliminary ……………………………

Comparision of Spectroscopic Factors with Other Reaction Probes

Ex (keV)	^{27}Al(d , t) present Exp.	Ex (keV) Reported	^{25}Mg(^{3}He,d)[1]	^{25}Mg(α, t)[2]	^{25}Mg(α, t)[3]
8329 (l=2)	0.21±0.03	8369			
(l=3)	0.15±0.05				
8563	0.11±0.03	8602			
9179	0.11±0.04	9264	0.17	0.20	0.22
10778	0.12±0.04	10660			
11312	0.17±0.06	11966	0.046	0.085	
13171	0.34±0.15	13250	0.015		

Preliminary … … … … .

- Spin assignment for 8563 keV from NNDC as 8531 keV.

References:

1: PRC 38,1130(1988).
2: PRC 33, 31 (1986).
3:PRC 39, 2159(1989).

Summary

- ✓ The reaction (d,t) has been studied , which was not done earlier to study the excited states of ^{26}Al. Different excited states have been produced through (d, t) reaction.

- ✓ The shape of angular distribution for 417 keV state in case of (d ,t) reaction at 25 MeV has been found to be same as theoretical prediction for l=2 transfer not for l=0 transfer.

- ✓ The shape of angular distribution for 8329 keV state in case of (d ,t) reaction at 25 MeV has been found to be close to theoretical prediction for l=3 transfer not for l=2 transfer.

- ✓ Signature of new excited states of ^{26}Al are found in the present study. Spectroscopic factors for new excited states have been extracted.

Preliminary

Preliminary

List of Collaborators

- Dr. C. Bhattacharya
- Dr. S. Bhattacharya
- Dr. Gopal Mukherjee
- Dr. Tilak Kumar Ghosh
- Dr. Kaushik Banerjee
- Dr. Samir Kundu
- Tapan Kumar Rana
- Pratap Roy

- Ratnesh Pandey
- Abhirup Chaudhri
- Tanmay Roy
- Md. Ali Asgar
- Dr. Aparajita Dey
- Dr. Mandira Sinha
- Dr. Subinit Roy
- Md. Moin Shaikh

Thank You