

# Additional Evaluation of Alpha Induced Neutron

## Production Nuclear Data

-  $^9\text{Be}$ ,  $^{27}\text{Al}$ ,  $^{28,29,30}\text{Si}$  -

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Though, JENDL ( $\alpha, n$ ) Reaction Data File 2003 has been released for 13 nuclides, additional nuclear data for the reaction are required. For  $^9\text{Be}$ , requirement of detailed angular distributions of neutrons to several excited states of  $^{12}\text{C}$  was made to analyze intensity of standard radio-active neutron source. Neutron production data of  $^{27}\text{Al}$  are necessary to investigate new type nuclear fuel of non-proliferate. The data for Si are necessary to estimate the neutron emission rate of high level radio-active vitrified solid which includes alpha emitting TRU.

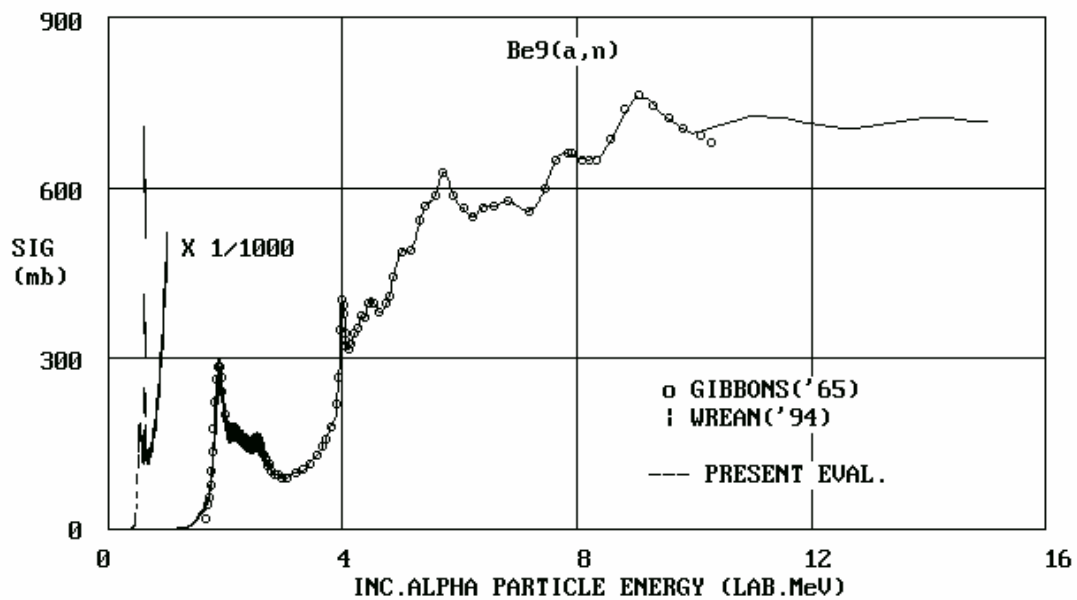
These cross sections were obtained by analyzing the experimental cross sections with a resonance formula and statistical model code EGNASH2<sup>1)</sup>. Evaluation of cross section was made by modifying the obtained cross section slightly to reproduce the experimental thick target neutron yields.

- 1) A revised version of GNASH code by P.G.Young and E.D.Arthur: LA-6947 (1977). The revision was made by some researchers of JNDC.

## $^9\text{Be}$

The following quantities are compiled in JENDL ( $\alpha, n$ ) Reaction Data File 2003

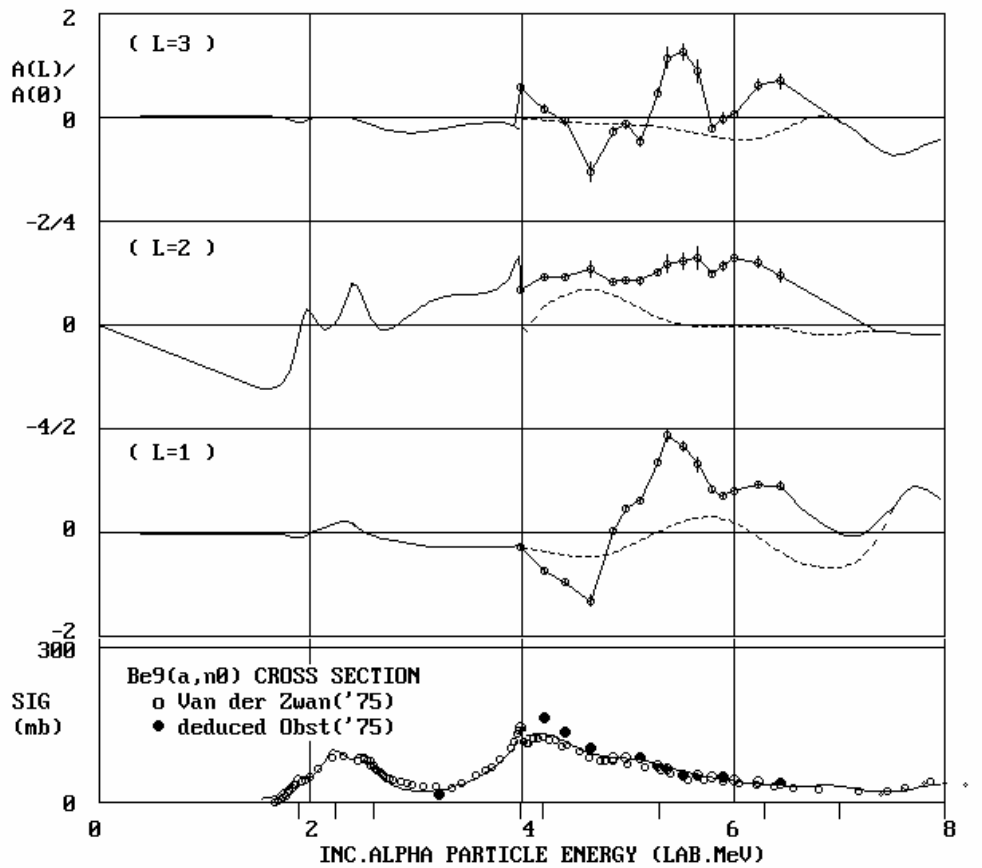
- Cross sections of the ( $\alpha, n_0$ ), ( $\alpha, n_1$ ), ( $\alpha, n_2$ ), ( $\alpha, n_3$ ), ( $\alpha, \alpha' n$ ), and ( $\alpha, n_T$ ) reactions
- Neutron spectrum calculated with a multistep statistical model code mEXIFON in the form of Kalbach systematics.



Neutron production cross section of the  $^9\text{Be}+\alpha$  reaction given in JENDL ( $\alpha, n$ ) Reaction Data File 2003

Present study

- Angular distributions of neutrons emitted by the reaction  $(\alpha, n_0)$ ,  $(\alpha, n_1)$ ,  $(\alpha, n_2)$  and  $(\alpha, n_3)$  evaluated on the experimental data by Obst et al.: Phys.Rev.C5,738(1972) and with resonance analysis.
- Continuum energy spectrum of neutrons were determined to reproduce the experimental data of Obst et al. approximately.



Present (tentative) evaluated  ${}^9\text{Be}(\alpha, n_0)$  cross section is shown in the bottom figure by solid line comparing with the experimental data by open circle; Van der Zwan ('75) and by closed one; deduced from angular distributions by Obst et al. Top three figures show Legendre coefficients ( $L=1, 2$  and  $3$ ) of  ${}^9\text{Be}(\alpha, n_0)$  angular distributions; evaluated (solid line), calculated with resonance parameters used to reproduce the bottom figure cross section (dashed line) and experimental ones obtained by analyzing angular distributions measured by Obst et al.('75).

## <sup>27</sup>Al

- Experimental Data:

Neutron counting method

B.Holmqvist, E.Ramstrom: Physica Scripta 33,107(1986)

Ea=3.05~3.661 MeV, 107 energy points

D.S.Flynn et al.: Phys.Rev. C18,1566(1978)

Ea=3.533~5.525 MeV, 269 energy points

R.H.Stelson, F.K.Mcgowan: Phys.Rev. B133,911(1964)

Ea=5.5~11.0 MeV, 30 energy points

Activation method

S.M.Sahakundu, S.M.Qaim, G.Stocklin: Applied Radiation and Isotopes 30,3(1979)

Ea=10.5~37.6 MeV, 15 energy points

A.J.Howard et al.: Astrophysical Journal, 188,131(1974)

Ea=3.05~3.66 MeV, 106 energy points

- Evaluation Method

Neutron production cross section was evaluated on the experimental data.

Resonance Region (Ea≤5.5MeV)

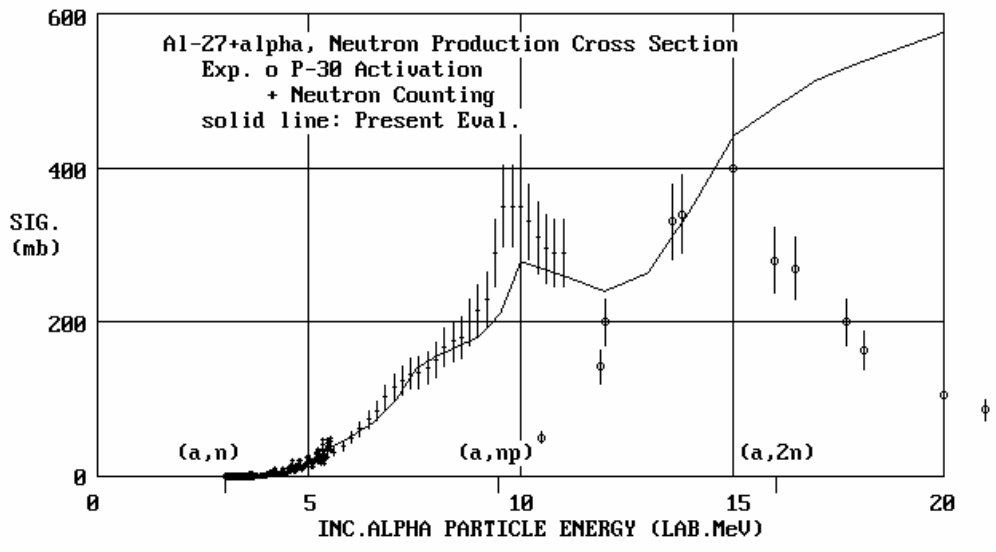
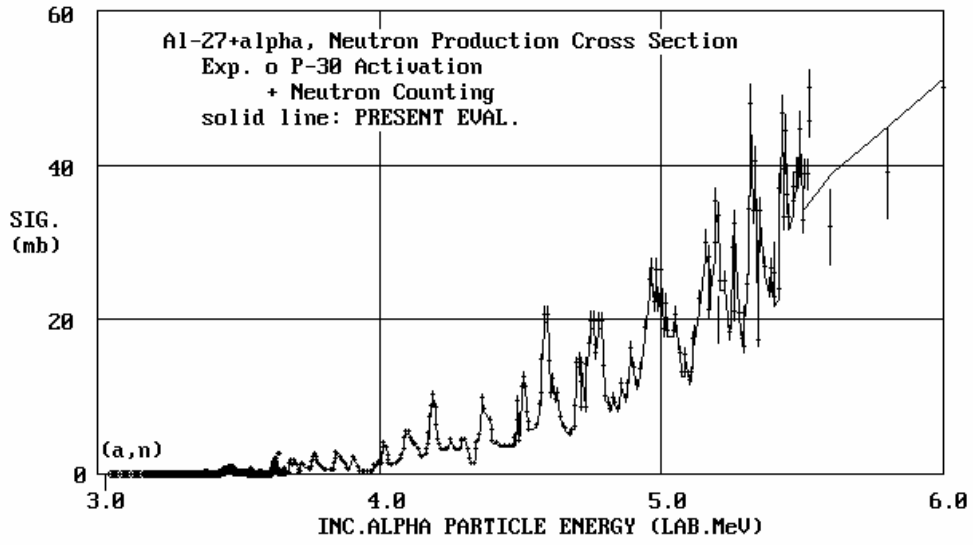
Experimental cross sections were reproduced with Lorentz type function.

Higher energy Region (Ea>5.5MeV)

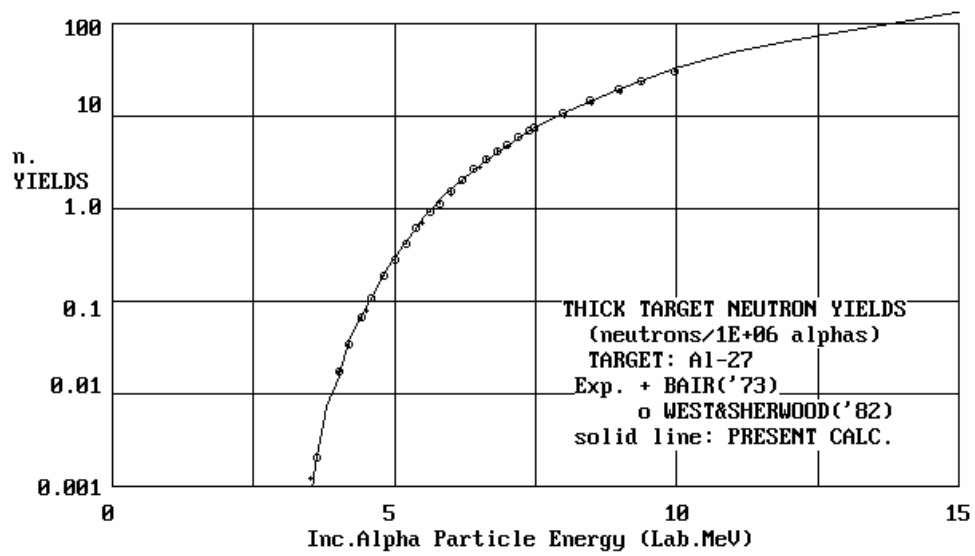
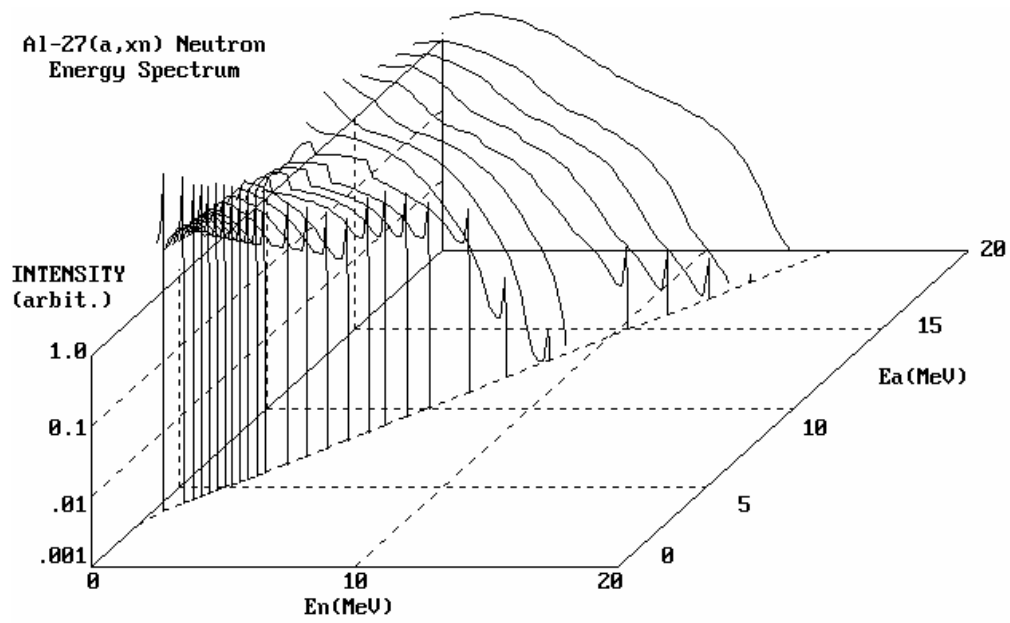
Calculated cross section with EGNASH2 code was normalized to the resonance region cross section.

Neutron Energy Spectrum

Calculated with EGNASH2 code in whole energy region



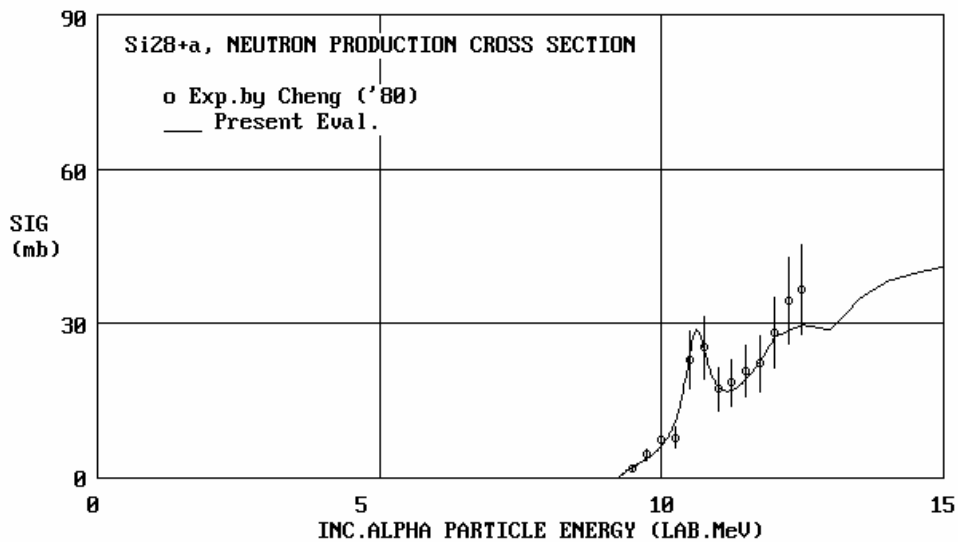
Al-27(a,xn) Neutron  
Energy Spectrum



## $^{28}\text{Si}$

### Experimental Data

C.W.Cheng,J.D.King: CJP,58,697,(1980) ; activation method



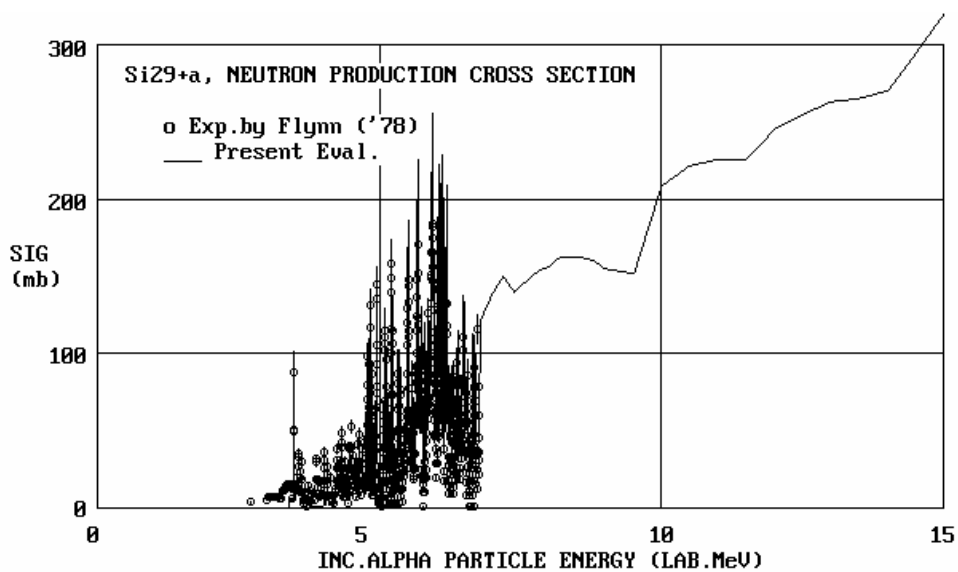
## $^{29}\text{Si}$

### Experimental Data

D.S.Flynn,K.K.Sekharab,B.A.Hiller,H.Laumer,J.L.Weil,F.Gabbaed:

PR/C,18,1566(1978); n.counting

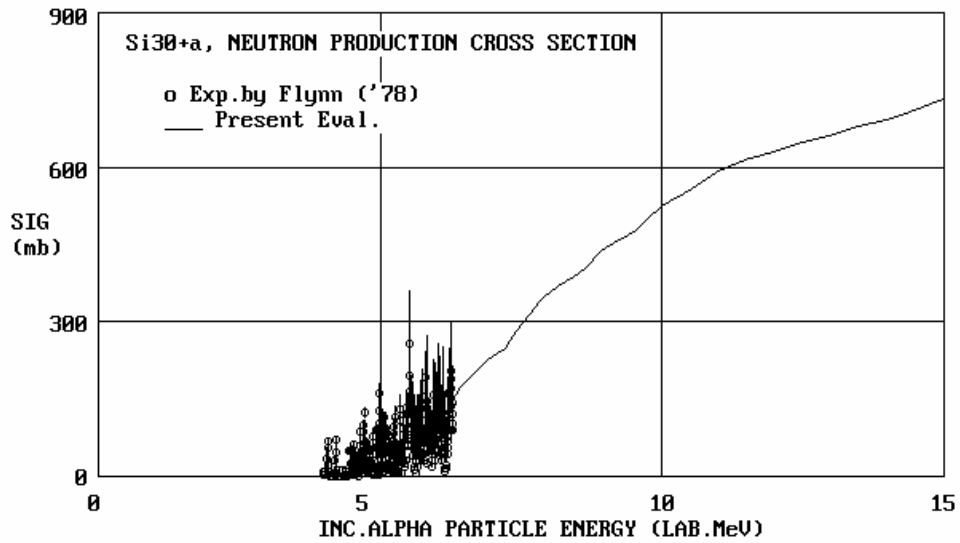
J.H.Gibbons,R.L.Macklin: PR,114,571(1959), n.counting



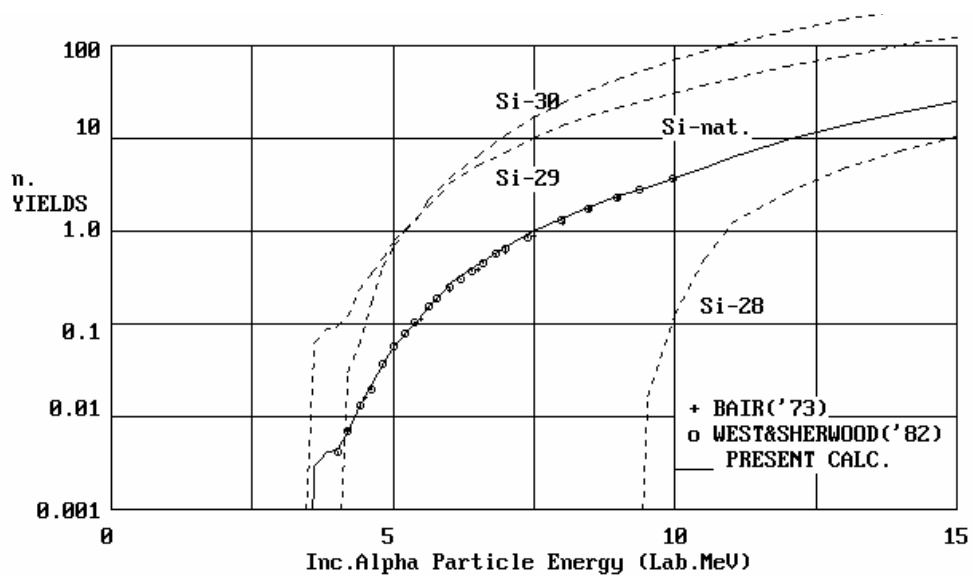
# $^{30}\text{Si}$

## Experimental Data

D.S.Flynn, K.K.Sekharan, B.A.Hiller, H.Laumer, J.L.Weil, F.Gabbard:  
PR/C, 18, 1566 (1978), neutron counting



## Si Thick Target Neutron Yields





## Conclusion

- For alpha particle bombardment of  $^{27}\text{Al}$ ,  $^{28}\text{Si}$ ,  $^{29}\text{Si}$  and  $^{30}\text{Si}$ , neutron production cross sections and emitted neutron energy spectrum were by evaluated on the experimental data and theoretical calculation.
- Angular distributions of neutrons emitted by the  $^9\text{Be}(\alpha, n_i)$ ,  $i=0, 1, 2$  and  $3$  were analyzed with a resonance formula, and compared with the experimental data. But, the agreement was not so good and further analysis including interference with some direct process would be necessary.