Predictability of Theory, and Collaboration with Experimentalists in CMNS

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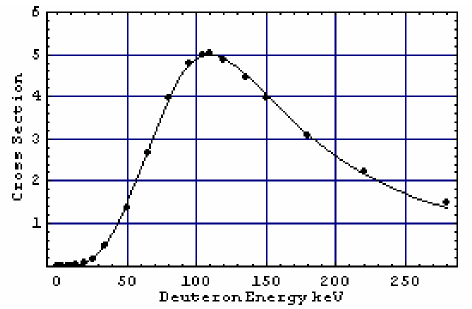
Notes by X. Z. Li

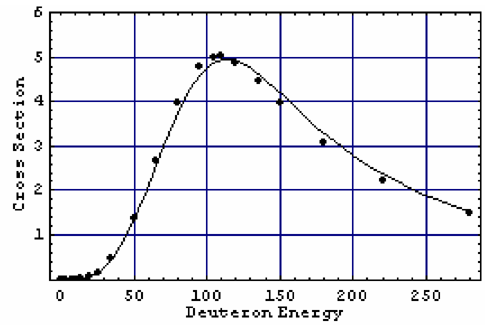
- Prof. T. Dolan – United Nation Officer, IAEA Coordinator for International Fusion Research (1995-2001), decided to use 3-Parameter formula instead of 5-Parameter formula for D+T Fusion Cross-Section in his Plasma Course at Univ. of Illinois, 2008.
- Because 3-Parameter formula is better than 5-Parameter formula not only in numbers but also in Physics.
- 3-Parameter formula shows the possibility of having nuclear reaction without strong neutron or gamma radiation.

5-Parameter formula has been listed in a Handbook , "NRL Plasma Formulary", since 1980. It was published by Naval Research Laboratory (NRL/PU/6790-07-500). Most of hot fusion scientists are still using this 5-Parameter formula without knowing the draw-back of this 5-Parameter formula.

Comparison with ENDF Data Points (d+t fusion)
3-Parameter formula is better than 5-Parameter formula



3-Parameter



5-Parameter

These figures show the comparison between two formulas in the energy range of 50 keV to 280 keV. The comparison at even lower energy is shown in the next slide.

3-Parameter formula is even better than 5-Parameter formula at Low Energy

Deuteron Energy (keV)	ENDF/B-VI (Barns)	3-Parameter Formula (Barns)		5-Parameter Formula (Barns)	
0.2	7.43E-39	7.65E-39		2.83E-40	
0.3	4.06E-31	4.17E-31		2.92E-32	
0.4	1.59E-26	1.63E-26		1.67E-27	
0.7	2.51E-19	2.59E-19		4.80E-20	
1	1.00E-15	1.06E-15		2.66E-16	
4	1.16E-06	1.21E-06		6.57E-07	

At low energy (200eV to 4 keV), our 3-parameter formula is even better than the NRL 5-parameter formula.

3-Parameter Formula is based on Selective Resonant Tunneling Model

$$\sigma_r(E) = \frac{\pi}{k^2}\frac{1}{\theta^2}\frac{-4w_i}{w_r^2 + (w_i - \frac{1}{\theta^2})^2}$$

Geometry factor

Gamow factor

W_r=0 for resonance

Resonance is effective only for w_i~ -1/θ².

Resonance is not effective if w_i>> -1/θ², or w_i<< -1/θ²

5-Parameter Formula is based on Compound Nucleus Model (Breit-Wigner theory)

Γ_r is the reaction width of a resonance. Fusion Reaction Cross Section increases with Γ_r. Hence, in this model Excess Heat must come with neutron because neutron channel has the greatest Γ_r

$$\sigma_r(E) = \frac{\pi}{k^2}\frac{(\Gamma - \Gamma_r)\Gamma_r}{(E-E_0)^2 + \frac{\Gamma^2}{4}}$$

E_0 is resonance energy

Γ is total width of resonance

The red marked part show the difference in physics on which 3-parameter formula and 5-parameter formula are based. Breit-Wigner formula is good only for the heavy or intermediate nuclei, but not valid for the light nuclei. However, most of hot fusion scientists are using 5-parameter formula without knowing this difference.

Conclusion

- **Fusion scientists need to know that: the beam-target experiments based on accelerator might not give the correct prediction for the deuteron-deuteron reaction in metal deuterides.**

- **Selective Resonant Tunneling Model shows clearly the selectivity of resonance, but compound nucleus model does not show it.**

- **Nuclear energy (Excess heat) without strong neutron or gamma radiation is possible**

Once the hot fusion scientists become aware of this draw-back in 5-parameter formula, they will accept the anomalies in metal deutrides.

The following additional slides are for scientists who would like to know more

$$\sigma(E)=\frac{(\pi\hbar)^2}{\mu E}\frac{\dfrac{-4B_1}{(B_2-B_3E)^2+\left[B_1-\dfrac{2\pi}{Exp[\frac{\sqrt{\frac{2}{\mu}}\pi\hbar}{\sqrt{E}a_c}]-1}\right]^2}}{Exp[\frac{\sqrt{\frac{2}{\mu}}\pi\hbar}{\sqrt{E}a_c}]-1}$$

$$\sigma(E)=\frac{((A_5+\dfrac{A_2}{((A_4-A_3E))^2+1)})}{E\ [\mathrm{Exp}(\frac{A_1}{\sqrt{E}})-1]}$$

B_1=-0.392,
B_2=0.542,
B_3=5.560 $\times 10^{-3}$

$a_c=4\pi\varepsilon_0\hbar^2/(\mu e^2)$

A1=45.95;
A2=50200;
A3=1.368$\times 10^{-2}$;
A4=1.076;
A5=409

Naval Research Laboratory Plasma Formulary provided a 5-parameter fitting formula:

$$\sigma(E) = \frac{\left(\left(A_5 + \dfrac{A_2}{((A_4 - A_3\, E))^2 + 1)}\right)\right.}{E\,\left[\mathrm{Exp}\left(\dfrac{A_1}{\sqrt{E}}\right) - 1\right]}$$. (in Barns)

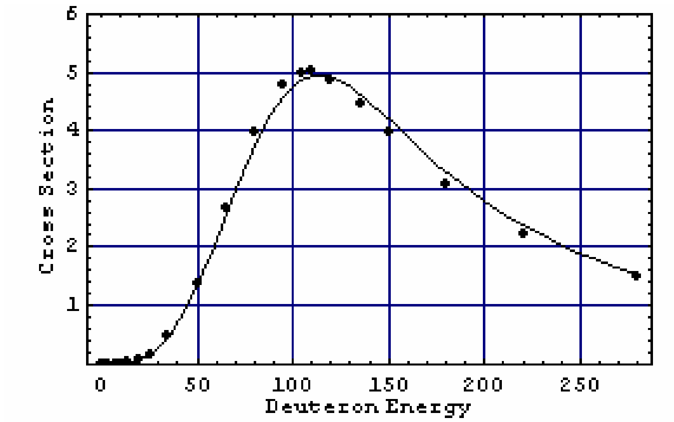
A_1=45.95;

A_2=50200;

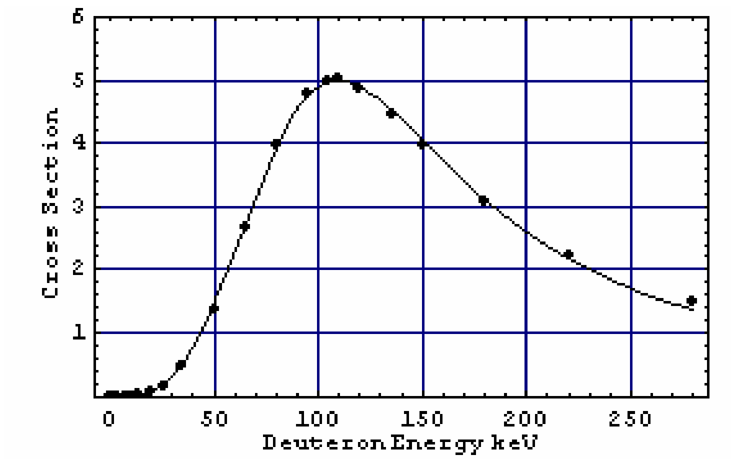
A_3=1.368×10^{-2};

A_4=1.076;

A_5=409.



Cross Section
Deuteron Energy
0
50
100
150
200
250
1
2
3
4
5
6


Cross Section
Deuteron Energy keV
0
50
100
150
200
250
1
2
3
4
5
6

$$\sigma(E) = 289\frac{\pi}{E}\frac{(-4B_1)}{(B_2 - B_3E)^2 + \left[B_1 - \frac{2\pi}{Exp[44.40/\sqrt{E}]-1}\right]^2}\left[\frac{2\pi}{Exp[44.40/\sqrt{E}]-1}\right]$$

$$\sigma(E) = \frac{\pi}{k^2} \frac{-4B_1}{(B_2 - B_3 E)^2 + \left[B_1 - \frac{1}{\theta^2} \right]^2} \frac{1}{\theta^2}$$

B1=-0.392,
B2=0.542,
B3=5.560 $\times$10-3.

$$\theta^2 = \frac{Exp[\frac{2\pi}{ka_c}] - 1}{2\pi} \qquad k^2 = \frac{2\mu}{\hbar^2} E$$

$a_c = 4\pi\varepsilon_0\hbar^2/(\mu e^2)$ – the length of Coulomb unit.