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Calculations of Complete Data for n+^{89}Y in the Energy Region 0.001 ~ 20 MeV

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Abstract

All reaction cross sections, secondary neutron spectra and elastic scattering angular distributions of n+^{89}Y in E_n=0.001 ~ 20 MeV are calculated. Pretty good results in accordance with experimental data are obtained. And the data results are given in ENDF/B-6 format.

Introduction

Among the large number of fission product nuclides, ^{89}Y is one of several very important nuclides for which there are abundant experimental data for σ_{tot} and elastic scattering angular distributions, sufficient experimental data for $\sigma_{n,\gamma}$ and $\sigma_{n,2n}$, some data for σ_{el}, $\sigma_{n,n'}$, $\sigma_{n,p}$ and $\sigma_{n,\alpha}$. There are no experimental data for other reaction cross sections and secondary neutron spectra. All of the experimental data were taken from EXFOR. The universal optical potential parameters for six channels used in calculations are given in Table 1.

Firstly, the code APMN[1] was used to automatically get the optimum parameters of optical potential for neutron channel. There are no experimental σ_{non} for ^{89}Y to search for the optimum optical potential parameters. They were calculated from experimental σ_{el} and $\sigma_{n,\gamma}$. The final optimum set of optical potential parameters for neutron channel are (the parameters not listed here are taken the same values as in Table 1):

V_0= 55.46697998, V_1= −0.62699956, V_2= 0.01931670, V_4= −0.09212393,
W_0= 4.56148911, W_1= 0.23274532,
U_0= −0.21403342, U_1= 0.38227317, U_2= −0.08095945,
a_r= 0.44500044, a_s= 0.40294382, a_v= 0.77707744,
r_r= 1.27821732, r_s= 1.37984145, r_v= 1.10318673.

Table 1 The universal optical potential parameters for six channels

channel	n	p	t	^{3}He	d	α
a_r	0.75,	0.75,	0.72,	0.72,	0.71,	0.520,
a_s	0.58,	0.51,	0.84,	0.88,	0.78,	0.520,
a_v	0.58,	0.51,	0.84,	0.88,	0.78,	0.520,
a_{SO}	0.75,	0.75,	0.72,	0.72,	0.71,	0.520,
r_r	1.17,	1.17,	1.20,	1.20,	1.17,	1.442,
r_s	1.26,	1.32,	1.40,	1.40,	1.30,	1.442,
r_v	1.26,	1.32,	1.40,	1.40,	1.30,	1.442,
r_{SO}	1.01,	1.01,	1.20,	1.20,	0.64,	1.442,
r_c	1.25,	1.25,	1.30,	1.30,	1.30,	1.250,
V_0	56.30,	54.00,	165.00,	151.90,	90.60,	164.700,
V_1	−0.32,	−0.32,	−0.17,	−0.17,	0.00,	0.000,
V_2	0.00,	0.00,	0.00,	0.00,	0.00,	0.000,
V_3	−24.00,	24.00,	−6.40,	50.00,	0.00,	0.000,
V_4	0.00,	0.40,	0.00,	0.00,	0.00,	0.000,
V_{SO}	6.20,	6.20,	2.50,	2.50,	7.13,	0.000,
W_0	13.00,	11.80,	46.00,	41.70,	12.00,	0.000,
W_1	−0.25,	−0.25,	−0.33,	−0.33,	0.00,	0.000,
W_2	−12.00,	12.00.	−110.00,	44.00,	0.00,	0.000,
U_0	−1.56,	−2.70,	0.00,	0.00,	0.00,	22.400,
U_1	0.22,	0.22,	0.00,	0.00,	0.00,	0.000,
U_2	0.00,	0.00,	0.00,	0.00,	0.00,	0.000,

Secondary, the code DWUCK4[2] was used to calculate the cross sections and angular distributions of direct inelastic scattering to 6 levels. These direct inelastic scattering data and the optimum set of optical potential parameters were taken as the input data of the kernel program SUNF[3]. Through adjusting some parameters in the input data of SUNF by hand again and again, the cross sections $\sigma_{n,\gamma}$, $\sigma_{n,n'}$, $\sigma_{n,2n}$, $\sigma_{n,p}$ and $\sigma_{n,\alpha}$ were made in optimum agreement with experimental data.

The final optimum values of the adjusted parameters we got are:

C_k=2350 (the parameter for exciton model);

C_{el}=0.34 (the multiplied factor in $\sigma_{n,\gamma}$);

The optical potential parameters for p, α were adjusted as follows:

for p channel, a_r and a_{SO} to 0.63, a_s and a_v to 0.51, r_s and r_v to 1.24;

for α channel, a_s and a_v to 0.55, r_r and r_{SO} to 1.40, r_s and r_v to 1.39;

The change of energy density parameters are as follows:

$a_{n,n'}$ from 9.37206 to 10.37206, $a_{n,p}$ from 9.92813 to 12.88813, $a_{n,\alpha}$ from 11.21302 to 13.35302, $a_{n,d}$ from 9.76237 to 10.36237, $a_{n,2n}$ from 10.81555 to 15.81555;

The change of pair energy corrections are as follows:

$\Delta_{n,\gamma}$ from 0.39 to 0.19, $\Delta_{n,n'}$ from 1.49 to 0.49;

The calculated σ_{tot}, σ_{non} and σ_{el} with the experimental data are given in Fig. 1(a) and (b), from which we can see that calculated σ_{tot} are in very good accordance with experimental data except in E_n<0.4 MeV energy region, σ_{non} and σ_{el} are also in reasonable good accordance with experimental data. The results of $\sigma_{n,\gamma}$ are given in Fig. 2, from which we can see that the calculated values are in pretty good agreement with experimental data except in E_n>5 MeV energy region. The calculated and experimental $\sigma_{n,n'}$ and $\sigma_{n,2n}$ are given in Fig. 3, from which we can see that the calculated $\sigma_{n,2n}$ are in very good agreement with experimental data and B. S. Yu's evaluated values, the calculated $\sigma_{n,n'}$ are also in pretty good consistent with experimental data. The calculated and experimental $\sigma_{n,p}$ and $\sigma_{n,\alpha}$ are given in Fig. 4, from which we can see that the calculated $\sigma_{n,\alpha}$ are in very good agreement with experimental data, and the calculated $\sigma_{n,p}$ are not in very good accordance with experimental data because the experimental data themselves are some divergent. All calculated cross sections are plotted in Fig. 5, which are of reasonable values. There are experimental and calculated elastic scattering angular distributions at 60 energy points, only ten of them are given in Fig. 6 to Fig. 8, from which we can see that calculated values are in pretty good agreement with experimental data (for other 50 energy points, calculated values are in similar accordance with experimental data). The calculated secondary neutron spectra of continuous inelastic scattering (MT=91) and (n,2n) reaction (MT=16) at E_n=8.0, 14.0 MeV and 20.0 MeV are plotted in Fig. 9 and Fig.10, respectively. These secondary neutron spectra are of reasonable shapes in physics, though there are no experimental data to compare with.

References

[1] Shen Qingbiao, APMN, a code for automatically searching for a set of optimal optical potential parameters of medium and heavy nucleus (unpublished)

[2] P. D. Kunz, DWBA code DWUCK4, University of Colorado, USA (unpublished)

[3] Zhang Jingshang, SUNF, a code for comprehensive calculations of fission product nucleus based on unified model, CNDC, CIAE (unpublished)

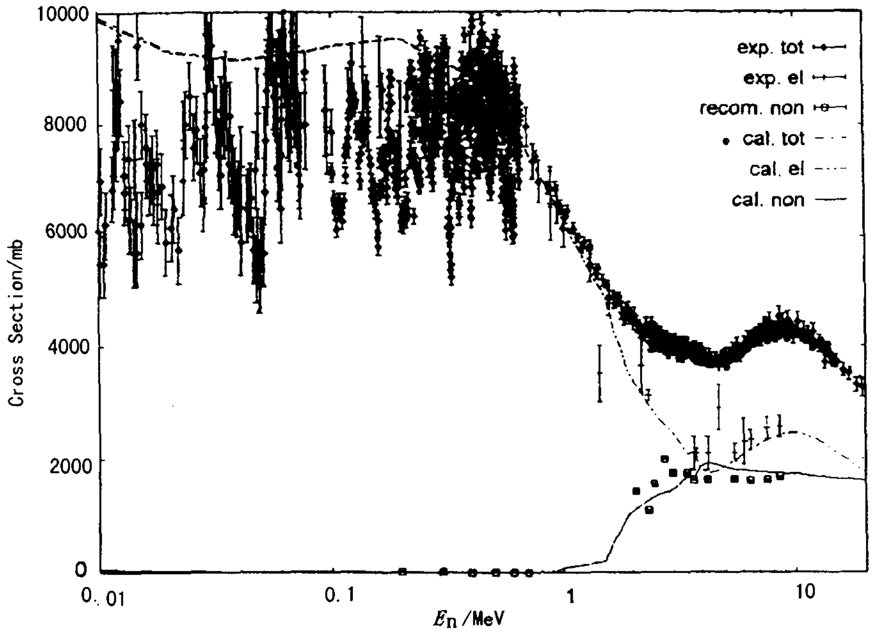

Fig. 1 ^{89}Y total, elastic and nonelastic cross sections energies of incoming neutron in L-frame (MeV)

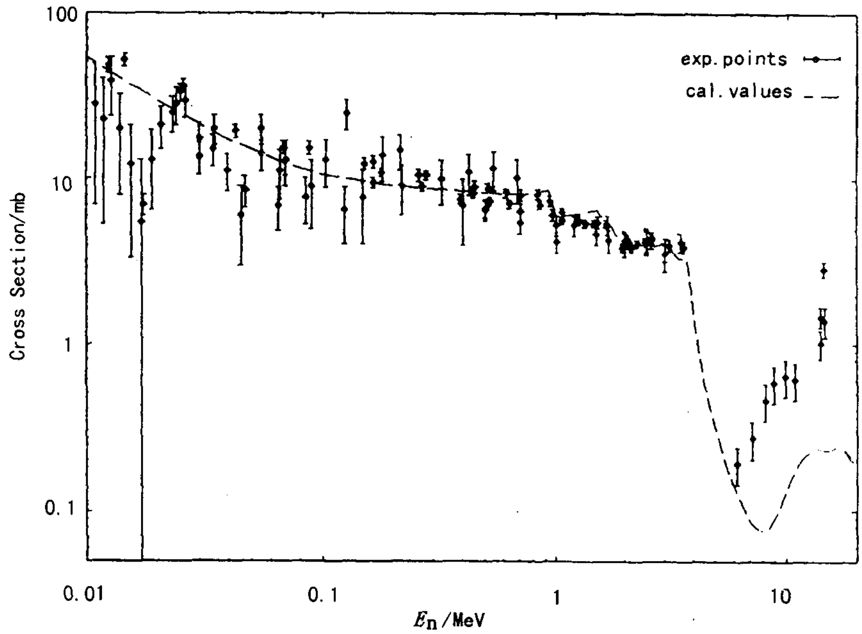

Fig. 2 ^{89}Y(n,γ) cross sections energies of incoming neutron in L-frame (MeV)

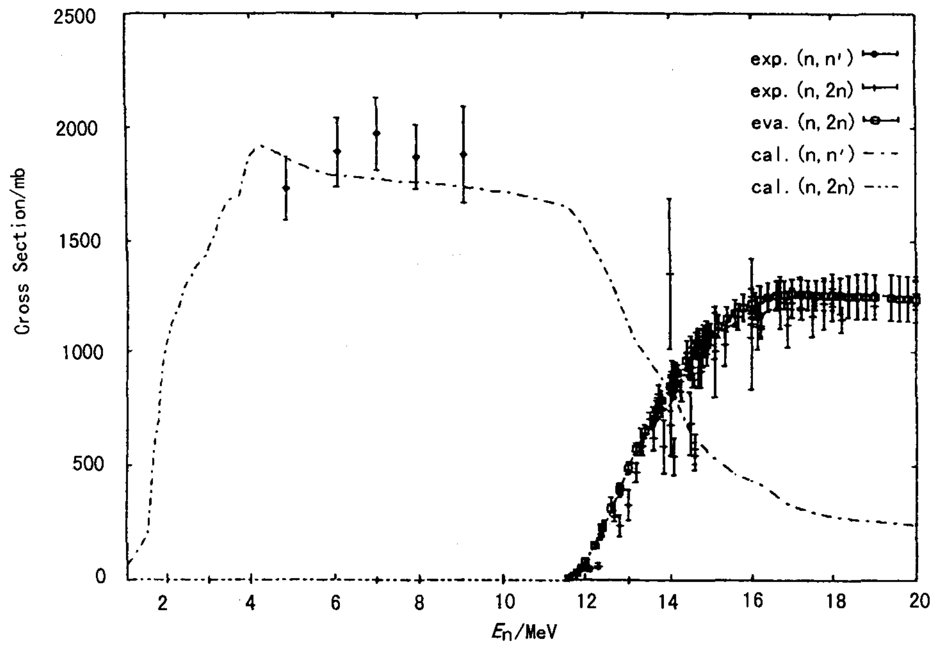

Fig. 3 ^{89}Y(n,n') and (n,2n) cross sections energies of incoming neutron in L-frame (MeV)

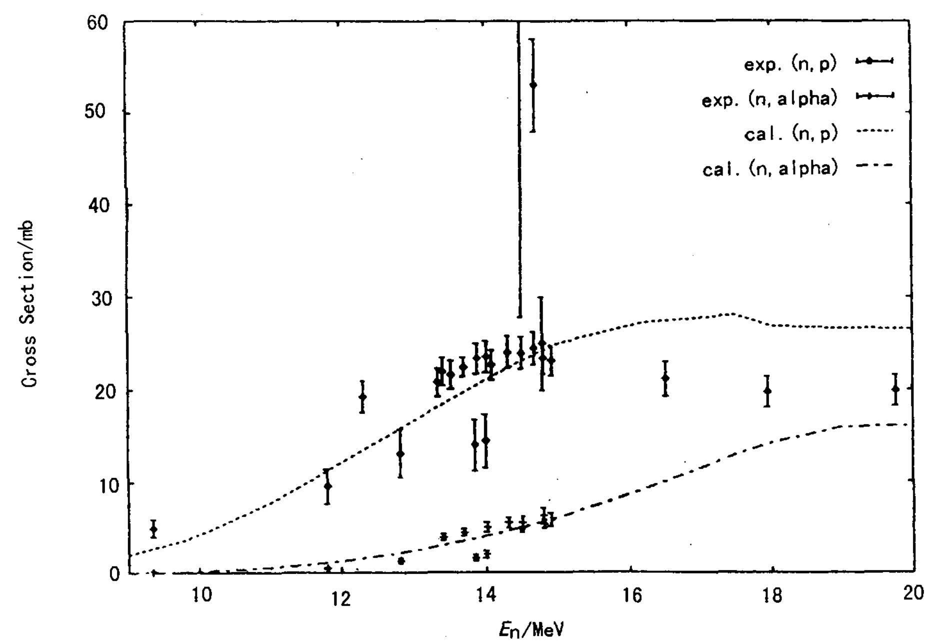

Fig. 4 ^{89}Y(n,p) and (n,α) nonelastic cross sections energies of incoming neutron in L-frame (MeV)

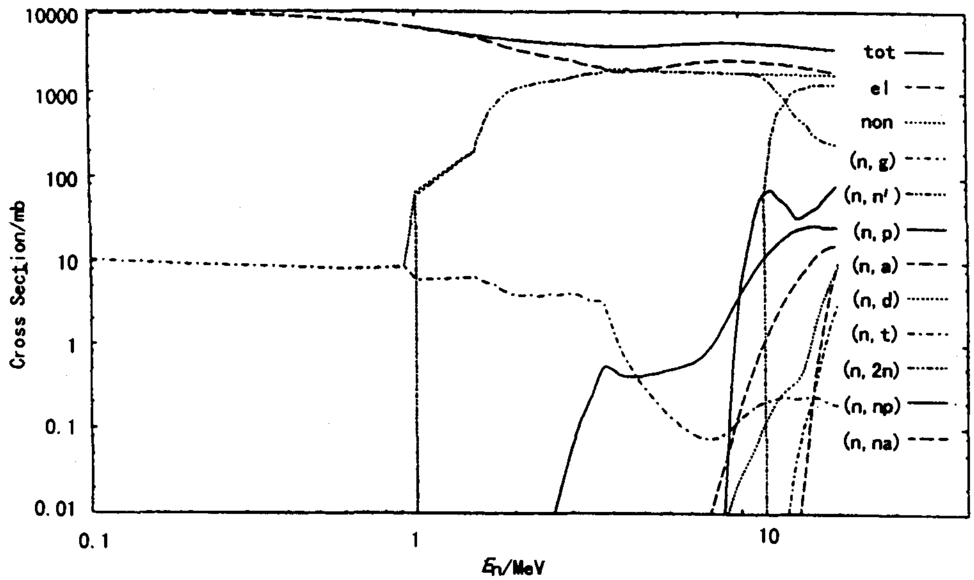

Fig. 5 n+^{89}Y cross sections energies of incoming neutron in L-frame (MeV)

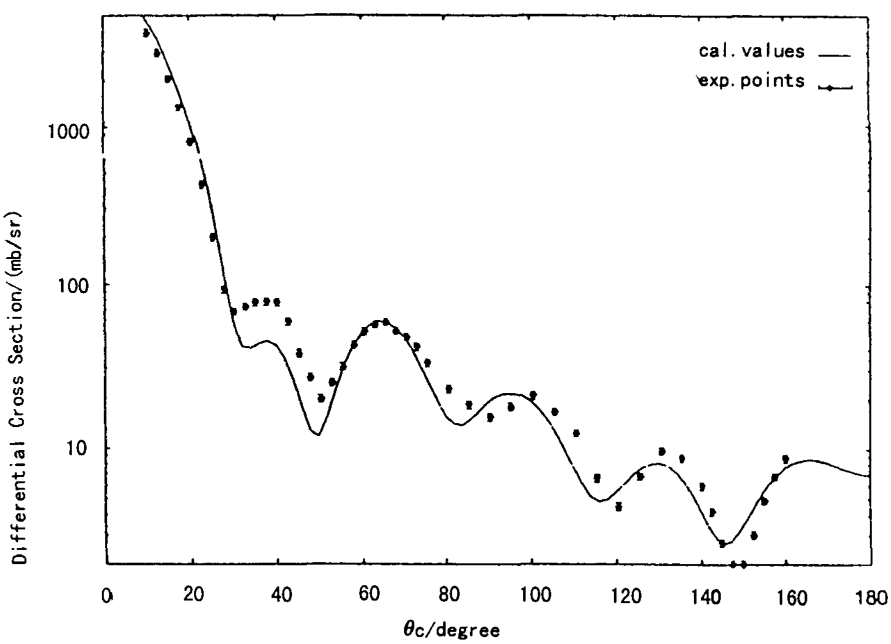

Fig. 6 ^{89}Y elastic differential C. S. at E_l=21.6 MeV angles (degree) of outgoing n in CM-frame (MeV)

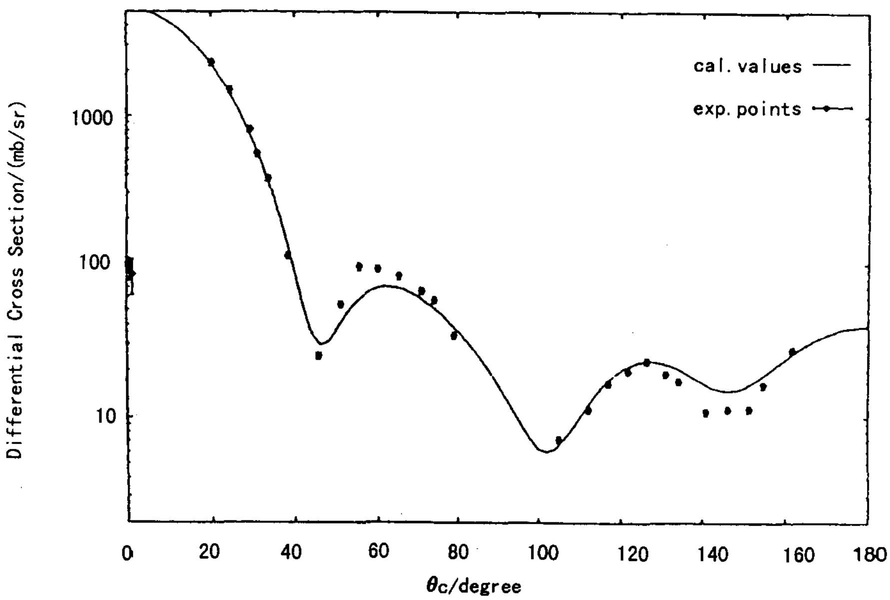

Fig. 7 ^{89}Y elastic differential C. S. at E_f=9.95 MeV angles (degree) of outgoing n in CM-frame (MeV)

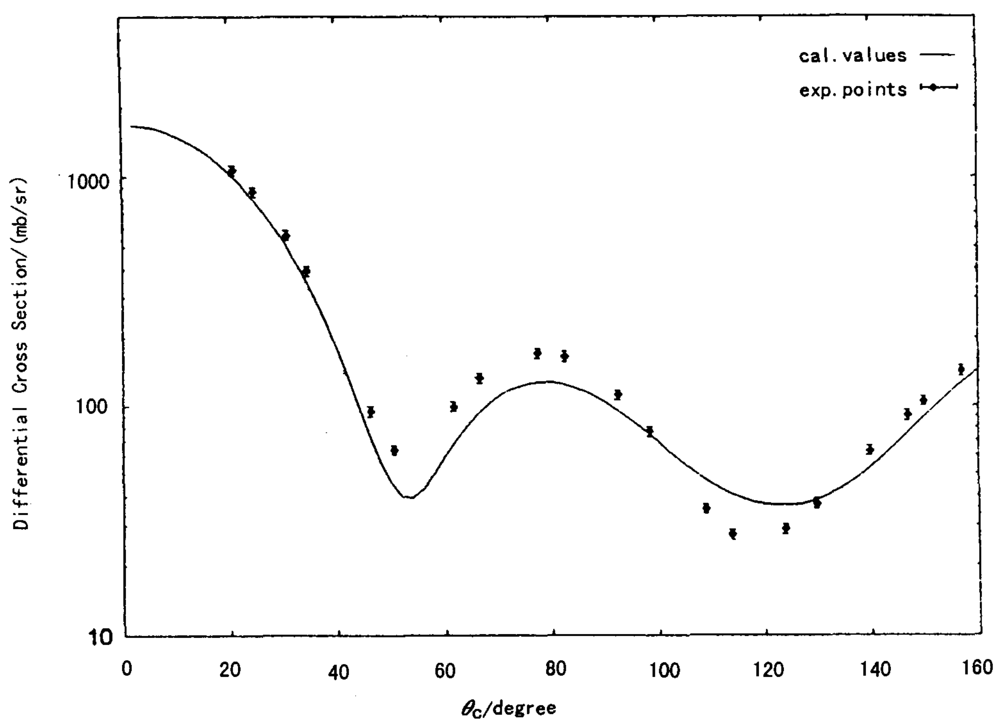

Fig. 8 ^{89}Y elastic differential C. S. at E_f=3.72 MeV angles (degree) of outgoing n in CM-frame (MeV)

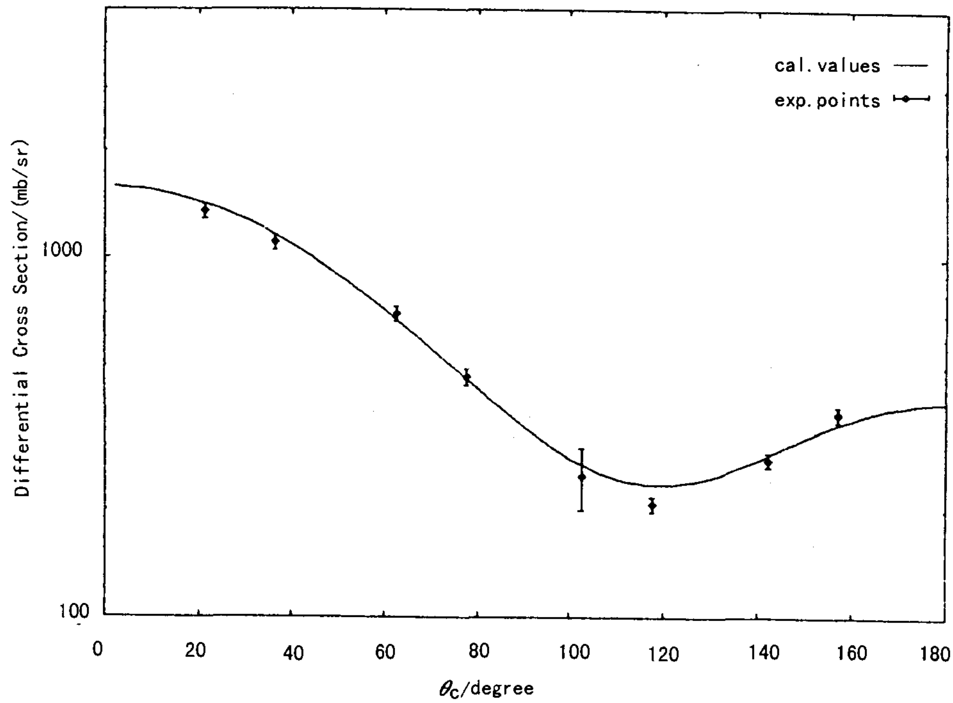

Fig. 9 ^{89}Y elastic differential C. S. at E_I=0.889 MeV angles (degree) of outgoing n in CM-frame (MeV)

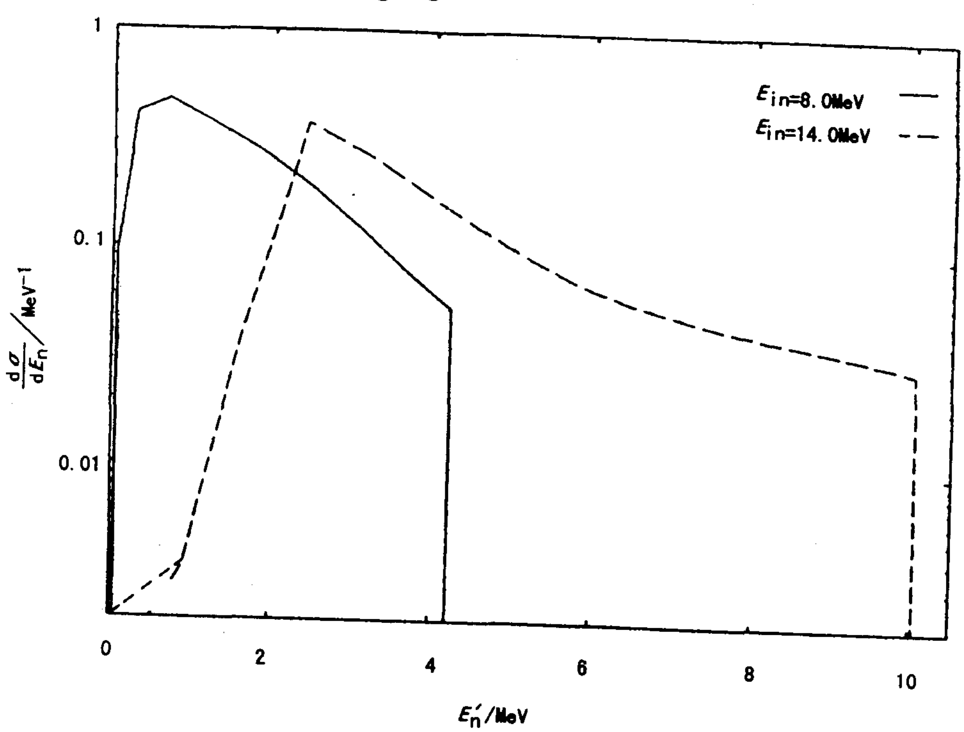

Fig. 10 ^{89}Y energy spectra of continuous inelastic scattering energies of outgoing neutron (MeV)