EFF-DOC-485

Contract NET/95-390

Status report on: Evaluation of the double-differential neutron emission cross sections of ^{9}Be.

S. Tagesen and H. Vonach
I.R.K., University of Vienna

and

V. Pronyaev
I.P.P.E., Obninsk

Follow-up of EFF Doc-431 (Jan. 1996)

Following our planed schedule, Beynons reaction modelling code /1/ was revised to account for all reaction mechanisms which possibly might contribute significantly to neutron emission. Particular attention was given to 3-body breakup channels which had not been considered so far /2, 3/. A summary of all 2- and 3-body decay modes which are taken into account is given in fig.1. Since up to now only neutron spectra/angular distributions are requested, decays are not followed after ^{8}Be, producing subsequently only alpha particles.

Table 1 lists all channels and expected branching ratios, proceeding through any of the excited states of ^{9}Be, attainable by incident neutron energies of up to 20 MeV. Most of the data were taken from /4/, for the particularly important decay modes of the second excited level of ^{9}Be information was combined from /3,5 and 6/. For the levels 7 (6.38 MeV) and 8 (6.76 MeV) complementary information was used from /7/.

Characteristics of intermediate nuclei in sequential reaction chains and Q-values between ^{9}Be ground state and ground state of the product nucleus are summarized in table 2.

A few general comments apply to the data in both of the tables:

- Table 1 contains all levels which could be excited by neutrons with energies up to 20 MeV, some of the excitation cross sections may, however, be negligibly small and have consequently been neglected in the reaction calculations.

- Gamma decay widths known for a few levels are at the order of several eV, which is many orders of magnitude below particle decay widths. This decay mode has therefore been excluded from consideration. This decision is further supported by results of gamma production cross section measurements reported in the literature.

- Alpha particle decay widths of ^{9}Be-states possibly increase considerably with excitation energy. Consequently branching ratios for alpha decay modes may be substantial, when neutron widths are small for any reason.

The angular distributions for neutron inelastic scattering with strong excitation of distinct levels, e.g. level 2, 7 and 8, have been taken as anisotropical, because the direct reaction mechanism contributes substantially to the cross sections at high neutron energy. The

Legendre coefficients describing angular anisotropy in the center of mass system as given in table 3 were evaluated for the second level and taken identical for all other levels.

For all steps in sequential decays except the first, it was assumed, that decay of any composite particle is not dependent on the mode of formation. This is accomplished by taking the differential distributions for an n-body particle decay as constant in a vector momentum space (n-body free space kinematics). This simplification is not permitted in reactions with at least two charged particles in the outgoing channels, because Coulomb forces may introduce significant deviations from free-space kinematics. This could be proven in the case of the (n, n' (n'' a' a'') three-particle breakup reaction channel, where an experimentally measured neutron spectrum is available for comparison - see figure 2.

First preliminary results of cross section adjustments.

For the adjustment procedure with the evaluation-update code GLUCS only those channels have been considered, which contribute significantly to the integral cross section. In addition, reactions passing through the same first inelastic scattering step, then proceeding by different reaction chains with sufficiently well known branching ratios, have been summed up into one „reaction channel" to reduce the total number of required channels in the adjustment procedure.

„Prior" double differential cross sections were prepared for incident neutron energies of 5.9 MeV, 10.1 MeV and 14.1 MeV according to the availability of experimental data /8, 9, 10/. The secondary neutron energy spectra were calculated for 7 (8) angles respectively. Prior integral cross sections for each reaction channel were taken from experimental data where they were available and estimated from theoretical considerations with an assigned uncertainty of 100% otherwise. Table 4 summarizes the details of a GLUCS runs for the incident neutron energy of 14.1 MeV.

REFERENCES

/1/ T. D. Beynon, B. S. Sim, Ann. Nucl. En 15, 27 (1988)
/2/ D. Ferenc, B. Antolkovic, G. Paic et al., Nucl. Sci. Eng., 101, 1 (1989)
/3/ O.V. Bochkarev, Yu.O. Vasilév, A.A. Korsheninnikov et al., Sov. J. Nucl. Phys. 52, 964 (1990)
/4/ F. Ajzenberg-Selove, Nucl. Phys. A490, 1 (1988)
/5/ O.Yu. Vasilév, A.A. Korsheninnikov, I.G. Mukha, and L.V. Chulkov, JETP Lett., 49, 622 (1989)
/6/ Y. S. Chen, T. A. Tombrello and R. W. Kavanagh Nucl Phys, A146, 136 (1970)
/7/ S. Dixt, W. Bertozzi, T.N. Buti et al. Phys. Rev., C43, 1758 (1991)
/8/ D. M. Drake, G. F. Auchampaugh, E. D. Arthur, C. E. Ragan and P. G. Young, Nucl. Sci. Eng., 63, 401 - 412 (1977)
/9/ A. Takahashi, E. Ichimura, Y. Sasaki and H. Sugimoto, Rep OKTAV-A-87-03 (1987)
/10/ M. Baba, M. Ishikawa, T. Kikuchi, H. Wakabayashi and N. Hirakawa, Proc. Int. Conf. on Nuclear Data for Science and Technology, 30.5. - 3.6. 1988, Mito, Japan, 209 (1988)

Table 1

E_{level} [MeV]	Jπ	Γ_{total} [MeV]	Branching ratio for decay to				
			8-Be gs	8-Be 1*	5-He gs	5-He 1*	breakup
0.0 (g.s.)	3/2-	0.0	0.0	0.0	0.0	0.0	0.0
1.684	1/2+	0.217	1.00	0.0	0.0	0.0	0.0
2.4294	5/2-	0.00077	0.07	0.0	0.0	0.0	0.93
2.78	1/2-	1.08	1.00	0.0	0.0	0.0	0.0
3.049	5/2+	0.282	0.87	0.13	0.0	0.0	0.0
4.704	3/2+	0.743	0.13	0.87	0.0	0.0	0.0
5.59	3/2-	1.33	0.5	0.5	0.0	0.0	0.0
6.38	7/2-	1.21	0.02	0.55	0.43	0.0	0.0
6.76	9/2+	1.33	0.0	1.00	0.0	0.0	0.0
7.940	1/2-	1.00	0.50	0.50	0.0	0.0	0.0
11.283	9/2-	1.10	0.02	0.14	0.84	0.0	0.0?
11.81	5/2+	0.400	0.20	0.80	0.0	0.0	0.0?
13.79	5/2-	0.590	0.0	1.00	0.0	0.0	0.0
14.392	3/2-	0.000381	0.049	0.386	0.565	0.0	0.0
14.4	1/2-	0.8	0.5	0.5	0.0	0.0	0.0
15.1	7/2-	0.35	0.0	1.00	0.0	0.0	0.0
15.9	5/2-	0.31	0.0	1.00	0.0	0.0	0.0
16.672	5/2+	0.041	0.0	0.0	1.00	0.0	0.0
16.975	1/2-	0.00049	0.07	0.0	0.0	0.0	0.93
17.298	5/2-	0.20	0.0	1.00	0.0	0.0	0.0
17.493	7/2+	0.047	0.2	0.8	0.0	0.0	0.0

Table 2

Characteristics of 8Be, 5He and 6He states and Q-values between 9Be ground state and ground state of product nucleus or nuclei

Nucleus	N_{lev}	Q [MeV]	E_{lev}[MeV]	Jπ	Γ_{tot} [MeV]
8Be	0	-1.6654	0.0	0+	0.0000068
8Be	1		3.040	2+	1.50
8Be	2		11.40	4+	3.5
5He	0	-2.460	0.0	3/2-	0.60
5He	1		4.0	1/2-	4.
6He	0				
(naa)	0	-1.5700			

Q value for 2- body break up 9Be(n (5He5He))	-3.350 MeV
Q value for 2- body break up of 5He -> (n a)	+0.890 MeV.
Q-value for 3- body break up reaction 9Be(n,na5He)	-2.460 MeV.

Table 3

Legendre coefficients for description of inelastic scattering angular distributions with excitation of levels having a high direct reaction component.

incident neutron Energy [MeV]	a_1	a_2	a_3
5.9	0.09892	-0.00041	0.0490
6.97	0.08660	-0.00030	0.0429
7.97	0.11360	0.00080	0.0333
8.96	0.13010	0.00600	0.0282
9.96	0.16260	0.01640	0.0176
10.1	0.16500	0.01670	0.0179
10.95	0.18190	0.01710	-0.0024
12.04	0.22700	0.02500	0.0081
12.94	0.21500	0.01760	0.0146
13.94	0.24320	0.02880	0.0148
14.1	0.24340	0.02874	0.01472
14.94	0.24320	0.02880	0.0148

Table 4

Evaluated prior cross sections for different reaction channels and preliminary results from the following least squares adjustment by GLUCS .

En [MeV]	Ch. numb.	Channel components	BR	Prior Cs [mb]	Prior uncert. [%]	Final CS [mb]
14.1	1	9Be(n,n2′(n0′′8Be))	0.07	9.2	17.	9.3
14.1	1	9Be(n,n2′(n′′a′a′′))	0.93	121.8	17.	123.7
14.1	2	9Be(n,n7′(n1′′8Be*))	0.55	24.8	100.	26.1
14.1	2	9Be(n,n7′(a0′(n′′a′′)))	0.45	20.2	100.	21.2
14.1	3	9Be(n,n8′(n1′′8Be*))	1.0	70.0	100.	39.6
14.1	4	9Be(n,n9′(n1′′8Be*))	1.0	20.0	100.	19.1
14.1	5	9Be(n,a1′(n0′(n′′a′′)))	1.0	17.0	20.	17.8
14.1	6	9Be(n,a2′(n0′(n′′a′′)))	1.0	25.0	100.	30.5
14.1	7	9Be(n,(n′a′)(n′′a′′))	1.0	20.0	100.	10.1
14.1	8	9Be(n,n′n′′8Be)	1.0	51.0	100.	43.8
14.1	9	9Be(n,n′a′(n′′a′′))	1.0	81.0	100.	150.2
	Sum			460.0		491.4

Figure 1: Different decay modes considered in (kinematic) calculations

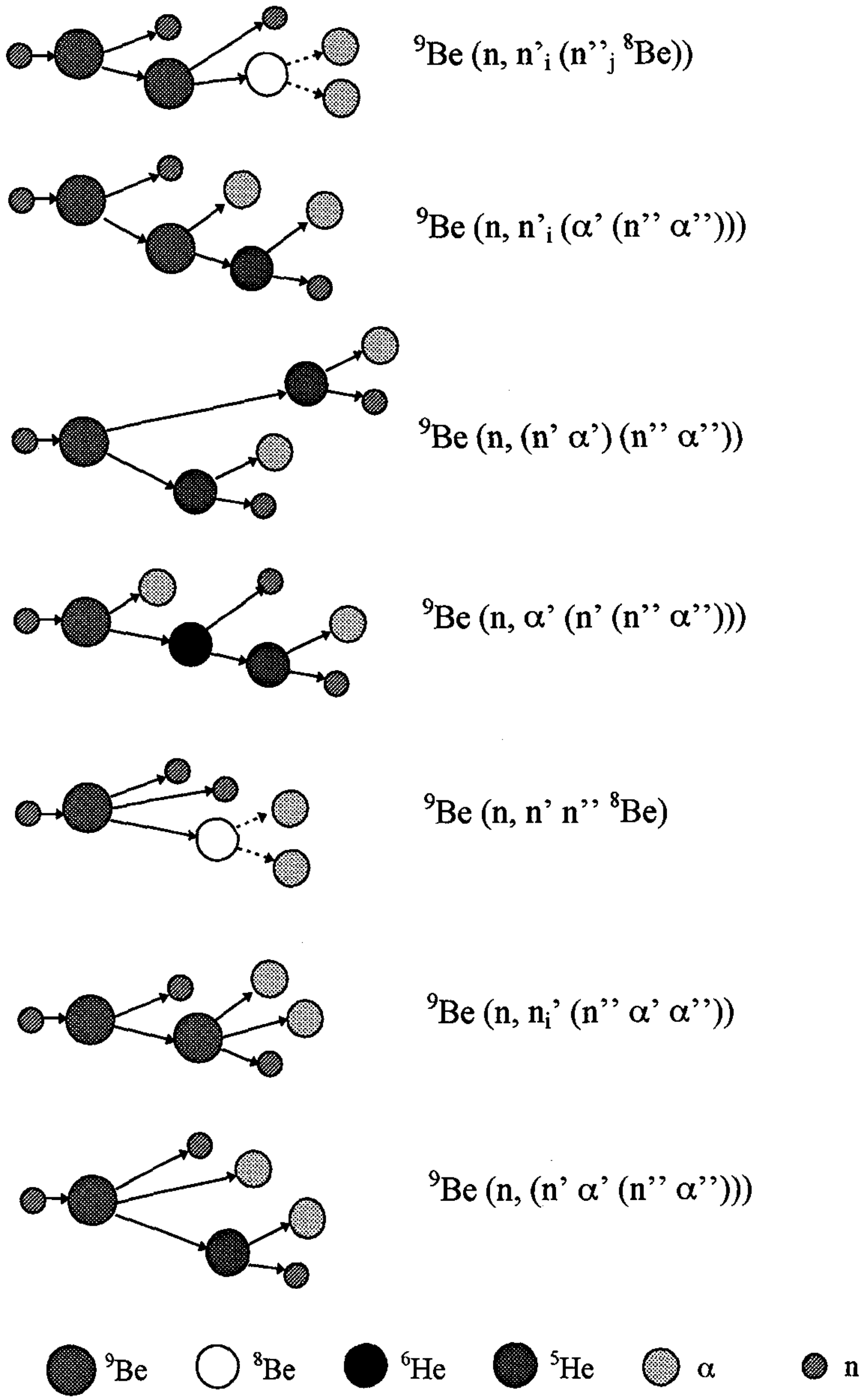
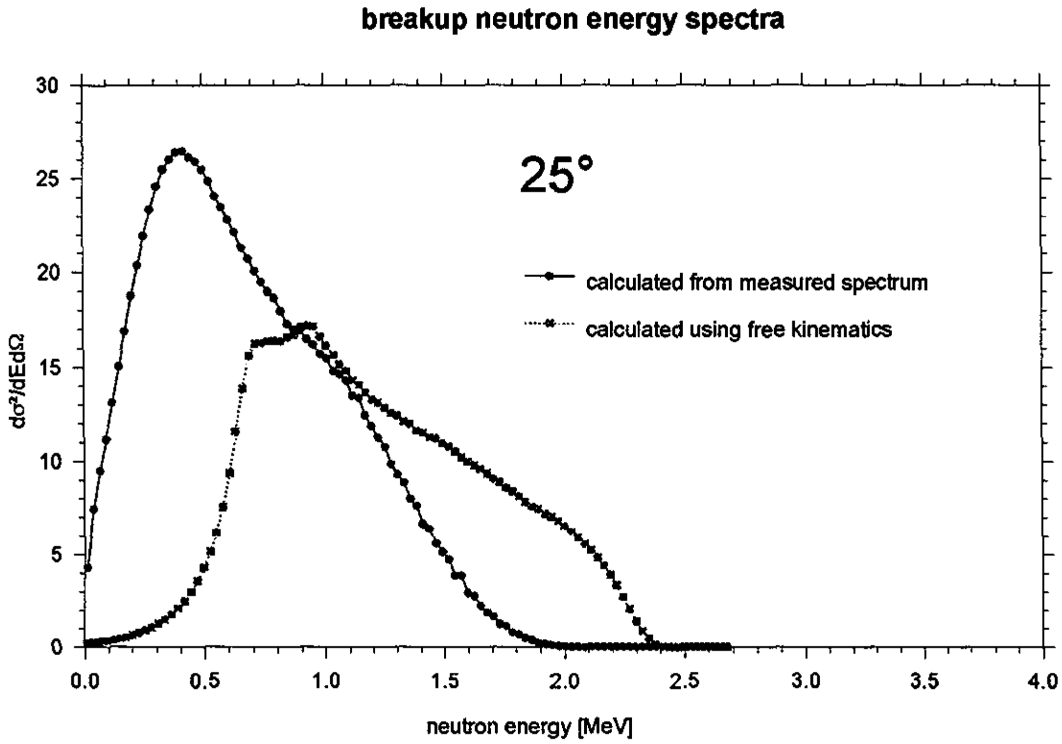


Figure 2: Influence of Coulomb forces on neutron spectral distribution



22240007