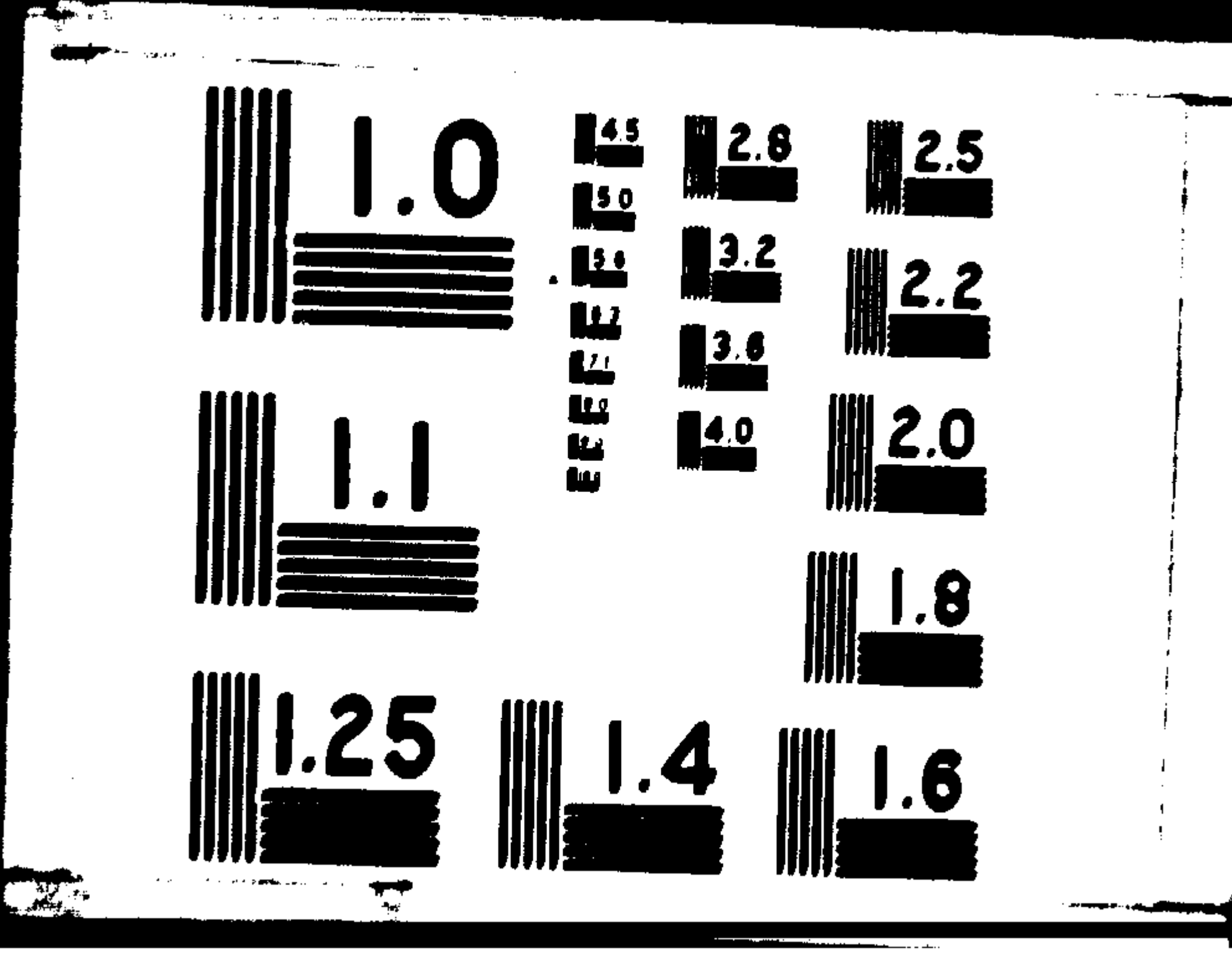
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0

Comitato Nazionale Energia Nucleare

KISS - A FORTRAN Code for Quadrupole Direct Radiative Capture Cross Section Calculation

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CONTENTS

KISS - A FORTRAN CODE FOR QUADRUPOLE DIRECT RADIATIVE CAPTURE CROSS SECTION CALCULATION

F. Fabbri, G. Longo and F. Saporetti *

1. INTRODUCTION

The main features of the FORTRAN programme KISS are described in this report. The code was written in order to calculate the cross section for quadrupole direct radiative capture of nucleons by nuclei. The dipole direct and collective capture cross section can be calculated by using the DIRCO programme [1], while the SPEC programme [2] is written for the calculation of the spectra of high energy photons following the capture of fast nucleons.

Here the particle is assumed to interact with a spinless target nucleus through a spherical optical potential including spin-orbit interaction. The details of the physical model and the theoretical formalism are described in paper [3].

The output data are the cross sections and the matrix element values (real part, imaginary and square) for individual transitions at a given nucleon energy; by option, the integrals and the wave functions can be printed versus the nuclear radius. The wave functions can also be plotted as functions of the nuclear radius. The plots of total and partial cross sections and of the radial integral squares versus the incident nucleon energy can be given, too.

The programme is particularly useful when the incident particle is a proton of relatively high energy (20-50 MeV). The code was used to investigate the $^{142}Ce(p,\gamma)$ reaction in the (10÷50) MeV energy range [3].

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This report contains the mathematical formulation, a detailed description of the programme written in FORTRAN IV language for an IBM 360/75 computer, the input list and the output data of a calculation for a test run.

2. MATHEMATICAL FORMALISM

2.1. Cross section

The direct mechanism describes the capture of a nucleon by a target nucleus as a transition from a continuum state to a single-particle bound state, with a simultaneous emission of a photon. According to the formalism of the mentioned paper [3], the cross section for quadrupole direct radiative capture of nucleons by nuclei can be written as

$$\sigma^{tot}(E2) = \frac{2\pi}{75}\frac{\bar{e}^2 M}{\hbar^2 k'} \sum_{\ell jj'} k_\gamma^5 |Q_{\ell jj'}|^2 \underline{Z}^2(\ell' j' \ell j; \tfrac{1}{2}\, 2) \quad , \qquad (1)$$

where $M = \frac{M_t M_i}{M_t + M_i}$ is the reduced mass and M_t and M_i are the mass of the target nucleus and incident nucleon, respectively; $\bar{e}$ is the effective nucleon charge given by

$$\bar{e} = \begin{cases} e\left(1 - \frac{2}{A} + \frac{Z}{A^2}\right) & \text{(for a proton)} \\ e\,\frac{Z}{A^2} & \text{(for a neutron)} \quad , \end{cases} \qquad (2)$$

with Z, N and A the proton, neutron and mass numbers of the target; ℓ', j' and ℓ, j are the quantum numbers of the initial and final states of the nucleon; k' and k_γ are the incident and photon wave numbers; $Q_{\ell' j'}$ is the quadrupole radial integral

$$Q_{\ell' j'} = \int u_{\ell j}(r)\, \psi_{\ell' j'}(r)\, r^2\, dr \quad , \qquad (3)$$

where $u_{\ell j}(r)$ and $\psi_{\ell' j'}(r)$ are the radial parts of the bound state and incident nucleon normalized wave functions, as defined in ref. [1]; the function $\underset{\sim}{Z}$ is a combination of Racah and Clebsh-Gordan coefficients given by

$$\underset{\sim}{Z}(\ell' j' \ell j; \tfrac{1}{2} 2) = -\, i^{\ell-\ell'} \left[(2\ell'+1)(2j'+1)(2\ell+1)(2j+1)\right]^{\frac{1}{2}} \cdot W(\ell' j' \ell j; \tfrac{1}{2} 2)(\ell' \ell 00 | 20) \quad . \tag{4}$$

The E2 selection rules permit only those transitions with $\Delta j = 0 \, , \pm 1 \, , \pm 2$ (no $0 \to 0$, no $\tfrac{1}{2} \to \tfrac{1}{2}$, no $0 \to 1$, no $1 \to 0$) and no change of parity.

Using masses, energies and lengths in a.m.u., MeV and fm respectively, the cross section (microbarns) for an individual single particle bound state (ℓ, j) may be written in the final form ready for computer calculation

$$\sigma_{\ell j}(E2) = 882 \cdot 10^{-9} \left(\frac{\bar{e}}{e}\right)^2 k'^5 \left(\frac{\epsilon_{1ab}}{M_i}\right)^2 \left[\frac{\epsilon_{\ell j}}{\epsilon_{1ab}} \frac{M_i + M_t}{M_t} + 1\right]^5 \sum_{j'} |Q_{j'}|^2 \, \underset{\sim}{Z}^2_{j'} \, , \tag{5}$$

where $k' = 0.218739 \sqrt{\epsilon_{j'} \, M}$, with $\epsilon_{\ell j}$ the nucleon energy in the final bound state, ϵ_{1ab} and $\epsilon_{j'}$ the incident energy in the laboratory and centre of mass systems, respectively. The $\underset{\sim}{Z}^2$ values of interest for quadrupole transitions can be calculated using the relations listed in Table I.

The code calculates expression (5) for all the possible final bound states and gives the total cross section as a sum of the contributions over all these states.

2.2. Interaction potentials

A detailed description of the optical and bound state potentials available in this programme is given in chapter 2 of ref. [1], which we assume is known to the reader. Here, only a small change has been introduced in the optical potential. This is assumed to have the more general form

$$U(r) = -\left[V_{vol} \, f_R(r) + V_{surf} \, g_R(r)\right] - i \left[W_{vol} \, f_I(r) + W_{surf} \, g_I(r)\right] - V_s h_s(r) \, \bar{\sigma} \cdot \bar{\ell} + \begin{cases} V_c(r) & \text{(for protons)} \\ 0 & \text{(for neutrons)} \end{cases} \, , \tag{6}$$

where the derivative Woods-Saxon term in the real part of the potential may be regarded as a symmetry potential arising from the excess neutrons in the target nucleus. The function $g_R(r)$ has the same form as $g_I(r)$ with the nuclear radius $R_R = \overline{r_{oR}} \, A^{1/3}$.

This addition is useful when the incident particle is a fast proton. Indeed, very good fits [4] are found in the elastic scattering of (20÷60) MeV incident protons using the reformulated Greenlees optical model [5], which considers the real central part of the optical potential formed by two components.

Here, we report the parameters of a potential for 30.3 MeV incident protons, as a further example of the "assigned potential" case of ref. [1], namely the SINHA, EDWARDS and SATCHLER-potential [4,6].

$$\begin{cases} V_{vol} = V_o + V_1 \epsilon_j \, , \text{ MeV}^{(*)} \\ r_{oR} = 1.128 \quad \text{fm} \\ a_R = 0.85 \quad \text{fm} \end{cases} \qquad \begin{cases} W_{vol} = 2.38 \quad \text{MeV} \\ r_{oI} = 1.287 \quad \text{fm} \\ a_I = 0.751 \quad \text{fm} \end{cases} \qquad \begin{cases} V_s = 5.85 \quad \text{MeV} \\ r_{os} = 1.152 \quad \text{fm} \\ a_s = 0.514 \quad \text{fm} \end{cases}$$

$$\begin{cases} V_{surf} = 8.037 \quad \text{MeV} \\ g_R = \text{derivative} \\ \overline{r_{oR}} = 0.865 \quad \text{fm} \\ b_r = 0.80 \quad \text{fm} \end{cases} \qquad \begin{cases} W_{surf} = 7.85 \quad \text{MeV} \\ g_I = \text{derivative} \\ \overline{r_{oI}} = 1.287 \quad \text{fm} \\ b_I = 0.751 \quad \text{fm} \end{cases} \qquad r_{oc} = 1.2 \quad \text{fm}$$

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* $(V_o = 52.52 \; ; \; V_1 = 0)$.

3. PROGRAMME

3.1. General description

The programme consists of a total of 19 subroutines:

1	Main routine	KISS
2	Subroutine	STLEG
3	"	POTSL
4	"	ROM
5	"	UINT
6	"	UEXT
7	"	BETA
8	"	FUX
9	"	DUX
10	"	FUNZ
11	"	WITTAK
12	"	PSQUA
13	"	POTSM
14	"	DOX
15	"	FOX
16	"	FGET
17	"	PLOTSQ
18	"	PINSQ
19	Function	DER

The subroutine DUMP is also used.

The programme assumes the presence of the following FORTRAN elementary function subroutines:

ALOG	(natural logarithm)	ATAN	(arc-tangent)
EXP	(exponential)	SQRT	(square-root)
SIN	(sine)	GAMMA	(gamma function)
COS	(cosine)		

and the standard routines for input/output.

The plots are made by CALCOMP; if this feature is not available, the programme could also be used without the PINSQ and PLOTSQ subroutines replacing them with two dummy subroutines.

The data are brought in from tape 5 and the whole output is on tape 6; all input data are read in by the main routine.

One tape is used as a temporary; the parameter N3, near the beginning of this programme, should be set to specify the temporary tape.

3.2. Detailed description of the specific routines

Main routine KISS controls the whole flow of the programme.

1) First the following input data are read in successively:
   a) a card containing alphanumeric information;
   b) control card: MPH, KPOT, KVV, KENER, KVS, KPLOT, KINT, KSTAMP;
   c) if KPLOT ≠ 0 are required: NSPER, AUTORE and XSPER(I), YSPER(I), DSPER(I), I=1, NSPER;
   d) FMTB, FMB, FMZ, FNU;
   e) RO, A, ROR, AR, RI, AI, RIS, BI, RSO, ASO, RC;
   f) V_o, V_1, V_S, W, WS, VSO, ENER(I), I=1, KENER;
   g) ROH, ABH, RCH, VSL;
   h) NH(I), LH(I), JH(I), EPH(I), VL(I), I=1, MPH.
2) Sets up a loop for varying IENER from 1 to KENER.
3) Computes the values of the potential depths V, W, WS, if they are required by input; computes FKAY and ETA, then prints out input data.
4) If IENER is equal to 1, calls STLEG, otherwise proceeds.

5) Calls PSQUA.
6) Increases IENER by 1 and returns to step 3 until IENER is equal to KENER.
7) If KPLOT is not equal to 0, calls PLOTSQ, otherwise proceeds.
8) If KINT is not equal to 0, calls PINSQ, otherwise proceeds.
9) Then returns to step 1.

STLEG calculates the bound-state wave function $u_{\ell j}(r)$ using the following subroutines: POTSL, FUNZ, ROM, UINT, UEXT, BETA. The function $u_{\ell j}(r)$ is stored on tape N3.

POTSL computes the ℓ- and ε-independent part of the potentials for the bound-state wave function in each mesh point to be used.

ROM computes the matching radius RM for the bound state.

UINT integrates the internal wave function from 0 to RM; calls subroutines DUX, FUX, DER.

UEXT integrates the external wave function from RMAX to RM. Calls subroutines WITTAK, DUX, FUX, DER.

BETA computes the normalization factor β .

FUNZ computes the form FVC of optical potential in bound state.

DUX computes differential equations.

FUX are two subroutines FUX1 and FUX2 that perform the numerical integration of a differential equation of the form $\psi'' = F\psi$, using the following expression

$$\psi_{i+1} = \frac{(2 + \frac{5}{6} h^2 F_i)\, \psi_i - (1 - \frac{1}{12} h^2 F_{i-1})\, \psi_{i-1}}{1 - \frac{1}{12} h^2 F_{i+1}} ,$$

where h is the integration step.

WITTAK computes the Wittaker function and its derivative.

PSQUA This subroutine controls the second part of the programme.
1) Computes the incident wave function $\psi_{\ell' j'}(r)$;
2) Computes the integrals $Q_{\ell j j'}$;

3) Computes the quadrupole direct cross section;

4) Outputs all these data.

Calls the subroutines POTSM, FGET, DOX, FOX, DER.

POTSM computes the ℓ-independent part of the potentials in each mesh point used for $\psi_{\ell' j'}$ functions.

DOX computes differential equations for $\psi_{\ell' j'}$.

FOX are two subroutines FOX1 and FOX2 that numerically integrate a system of differential equations.

FGET computes the regular and irregular Coulomb functions and their derivatives.

DER this function computes the derivatives by means of the equation

$$y_3' = \frac{1}{60h}\left[y_6 - y_o + 9\,(y_1 - y_5) + 45\,(y_4 - y_2)\right]$$

PLOTSQ plots the experimental and calculated cross sections.

PINSQ plots the integral squares $|Q_{\ell jj'}|^2$ at each energy.

3.3. Description of input data

The control data are:

MPH = number of bound states (≤ 20).

KPOT = 0, if the incident particle is a neutron.
= 1, if the incident particle is a proton.

KVV = -2 the real potential V is calculated by $V = V_o + V_1\varepsilon_j$, and used with volume + gaussian absorption.
= -1 the real potential V is calculated by $V = V_o + V_1\varepsilon_j$, and used with volume + surface absorption.
= 0 Rosen et al. potential.
= 1 Perey and Buck potential.
= 2 Becchetti and Greenlees potential.
= 3 Engelbrecht and Fiedeldey potential.
= 4 Sinha Edwards and Satchler potential.

KENER = number of energies of the incident particles (≤ 60).

KVS = 0, if in the bound state V_S is in input.
= 1, if in the bound state V_S is computed by formula (34) of the DIRCO programme [1].

KINT = 0, if the plot of $|Q_{\ell jj'}|^2$ is not required.
= 1, if the plot of $|Q_{\ell jj'}|^2$ is required.

3.4. Basic data

KISS code Symbol	Mathematical Symbol	Description
A	a_R	Diffuseness parameter in optical potential (real, volume)
ABH	a	Diffuseness parameter in bound state potential
AI	a_I	Diffuseness parameter in optical potential (imaginary, volume)
AR	b_R	Width parameter in optical potential (real, surface)
ASO	a_s	Diffuseness parameter in optical potential (spin-orbit)
AUTORE		Name of authors of experimental values
BI	b_I	Width parameter in optical potential (imaginary, surface)
DSPER	$\Delta\sigma_{ex}$	Error in experimental value of total cross section
DR	Δr	Integration step
ECM	$\varepsilon_{j'}$	Incident nucleon energy in C.M.S.
ELAB	ε_{lab}	Incident nucleon energy in laboratory system
ELEM		Alphanumeric description
ENER(I) I=1 to KENER	ε_{lab}	Location for incident energy in input
EPH	$\varepsilon_{\ell j}$	Single particle bound state energy
FMB	A	Mass number of target nucleus
FMIB	M_i	Mass of incident particle
FMTB	M_t	Mass of target particle

KISS code Symbol	Mathematical Symbol	Description
FMU	M	Reduced mass
FMZ	Z	Proton number of target nucleus
FNU	N	Neutron number of target nucleus
FKAY	k'	Wave number of incident nucleon
NH,LH,JH	n ℓ j	Bound state quantum numbers
NPASSI		Number of mesh points
NSPER		Number of experimental values
RC	r_{oc}	Coulomb radius parameter in optical potential
RCH	r_c	Coulomb radius parameter in bound state potential
RI	r_{oI}	Nuclear radius parameter in imaginary part of optical potential (volume)
RO	r_{oR}	Nuclear radius parameter in real part of optical potential (volume)
ROH	r_o	Nuclear radius parameter in bound state potential
RS	$\overline{r_{oI}}$	Nuclear radius parameter in imaginary part of optical potential (derivative or gaussian)
RSO	r_{os}	Spin orbit radius parameter in optical potential
ROR	$\overline{r_{oR}}$	Nuclear radius parameter in real part of optical potential (surface)
V	V	Depth of real part of central potential
VO, V1	V_o and V_1	See expression (28) of DIRCO code [1]
VI	v_1	Strength of symmetry term of optical potential
VL	V_B	Depth of bound state potential
VS	V_{surf}	Depth of real part of central potential (surface)
VSO	V_S	Depth of spin orbit term in optical potential
VSL	V_{BS} or λ	Depth of spin orbit term in bound state potential or parameter λ (see expression (34) of DIRCO code [1])

KISS code Symbol	Mathematical Symbol	Description
W	W_{vol}	Depth of imaginary part of optical potential
WS	W_{surf}	Depth of imaginary part of optical potential (derivative or gaussian)
XXX	x	Exchange force factor
XSPER		Experimental excitation energy
YSPER	σ_{exp}	Experimental cross section

3.5. Input cards

For computations referring to a single target nucleus, the following cards are required:

1) FORMAT (12A6) Alphanumeric data
2) FORMAT (1013) MPH, KPOT, KVV, KENER, KVS, KPLOT, KINT, KSTAMP
3) FORMAT (I3,3A4) NSPER, AUTORE
4) FORMAT (3E12.6) XSPER(I), YSPER(I), DSPER(I), I=1, NSPER
5) FORMAT (6E12.6) FMTB, FMB, FMZ, FNU
6) FORMAT (12E6.6) RO, A, ROR, AR, RI, AI, RIS, BI, RSO, ASO, RC
7) FORMAT (6E12.6) VO, V1, VS, W, WS, VSO, (ENER(I), I=1, KENER)
8) FORMAT (6E12.6) ROH, ABH, RCH, VSL
9) FORMAT (3F6.3, 2E12.6) NH, LH, JH, EPH, VL (are MPH cards)

3.6. Output

The standard output for each energy contains:

1) The alphanumerical information of card 1.
2) All input data of cards 4, 5, 6, 7.
3) For each single particle level: name, binding energy, corresponding potential and energy of γ-ray emitted. For each possible transition: quantum numbers ℓ' and j' of initial state, real and imaginary parts and squares of the integrals $Q_{\ell jj'}$. For capture to each final state: quadrupole direct cross sections.

4) If KSTAMP ≠ 0 prints also: the bound state wave function $u_{\ell j}(r)$; the real and imaginary parts of the continuum wave functions $Re\psi_{\ell' j'}(r)$, $Im\psi_{\ell' j'}(r)$; the radial integrals $ReQ_{\ell jj'}(r)$, $ImQ_{\ell jj'}(r)$, $|Q_{\ell jj'}(r)|^2$.

4. A SAMPLE CASE

As an example, the quadrupole direct radiative capture cross section of protons by the target nucleus ^{142}Ce is calculated at 32 MeV proton energy.

The control data are:

MPH = 4	KPOT = 1	KVV = 0	KENER = 8
KVS = 0	KPLOT = 1	KINT = 1	KSTAMP = 0

The parameters used are:

FMTB = 141.9091	FMB = 142.	FMZ = 58.
FNU = 84.	RO = 1.25	A = 0.65
ROR = 1.25	AR = 0.65	RI = 1.25
AI = 0.65	RIS = 1.25	BI = 0.7
RSO = 1.25	ASO = 0.65	RC = 1.25
VO = 0.	V1 = 0.	VS = 0.
W = 0.	WS = 7.5	VSO = 5.5

ENER(I) = 20. ; 24. ; 28. ; 32. ; 36. ; 40. ; 44. ; 48. ; 52.

ROH = 1.27	ABH = 0.67	RCH = 1.27
VSL = 33.		

NH(1) = 1.	LH(1) = 2.	JH(1) = 2.5	EPH(1) = 5.488	VL(1) = 56.
NH(2) = 0.	LH(2) = 5.	JH(2) = 5.5	EPH(2) = 3.872	VL(2) = 56.
NH(3) = 2.	LH(3) = 0.	JH(3) = 0.5	EPH(3) = 3.075	VL(3) = 56.
NH(4) = 1.	LH(4) = 2.	JH(4) = 1.5	EPH(4) = 2.950	VL(4) = 56.

The list of input cards and the output are given in Appendices 1 and 2.

The following plots are also given:

1) The quadrupole direct cross section versus the incident energy in the (20÷50) MeV energy range.

2) The partial cross section for capture leading to the $1h_{11/2}$ final bound state from all the initial states allowed by selection rules, as a function of energy in the (10÷50) MeV range.

3) The square of radial integral $Q_{\ell jj'}$ versus the incident proton energy in the (10-50) MeV energy range for the $j_{15/2} \rightarrow h_{11/2}$ transition.

5. TYPICAL RUNNING TIME

The time required to carry out the test case was 8" for each energy.

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TABLE I

z^2 values for quadrupole transitions

j'	$\frac{4}{15} z^2(j' j; \frac{1}{2}\ 2)$
j + 2	$\frac{(j + \frac{5}{2})\ (j + \frac{3}{2})\ (j + \frac{1}{2})}{(j + 2)\ (j + 1)}$
j + 1	$\frac{(j + \frac{3}{2})\ (j + \frac{1}{2})}{(j + 2)(j + 1)\ j}$
j	$\frac{2}{3}\frac{(j + \frac{3}{2})\ (j + \frac{1}{2})\ (j - \frac{1}{2})}{(j + 1)\ j}$
j - 1	$\frac{(j + \frac{1}{2})\ (j - \frac{1}{2})}{(j + 1)\ j\ (j - 1)}$
j - 2	$\frac{(j + \frac{1}{2})\ (j - \frac{1}{2})\ (j - \frac{3}{2})}{j\ (j - 1)}$

APPENDIX 1

LIST OF INPUT CARDS

SAMPLE PROBLEM ** KISS **

INPUT DATA

```
          CE-142 (P,GAM)   SIGMA(E)
 4  1  0  8  0  1  0
 0
 0.
 141.9091       142.          58.          84.
 1.25 0.65   1.25  0.65  1.25 0.65  1.25  0.7   1.25   0.65 1.25
 0.             0.            0.           0.          7.5          5.5
20.            24.           28.          32.          36.          40.
44.            48.           52.
 1.27           0.67          1.27         33.
 1.     2.     2.5    5.488        56.
 0.     5.     5.5    3.872        56.
 2.     0.     0.5    3.075        56.
 1.     2.     1.5    2.950        56.

          CE-142  SIG(1H 11/2)
 1  1  0 10  0  1  0
 0
 0.
 141.9091       142.          58.          84.
 1.25 0.65   1.25  0.65  1.25 0.65  1.25  0.7   1.25   0.65 1.25
 0.             0.            0.           0.          7.5          5.5
 10.            14.           18.          22.          26.          30.
 34.            38.           42.          46.          50.
 1.27           0.67          1.27         33.
 0.     5.     5.5    3.872        56.
          CE-142   Q2( H 11/2)
 1  1  0 10  0  0  1
 141.9091       142.          58.          84.
 1.25 0.65   1.25  0.65  1.25 0.65  1.25  0.7   1.25   0.65 1.25
 0.             0.            0.           0.          7.5          5.5
 10.            14.           18.          22.          26.          30.
 34.            38.           42.          46.          50.
 1.27           0.67          1.27         33.
 0.     5.     5.5    3.872        56.
```

APPENDIX 2

TEST RUN OUTPUT

CE-142 (P,GAM) SIGMA(E) ** KISS **

TARGET + INCIDENT PARTICLE A= 142.0 Z= 58.0 N= 84.0 MT= 141.9091 MI= 1.0073

ELAB= 32.00 ECM= 31.77

BOUND STATE PARAMETERS LAM= 33.000 A= 0.670 RO= 1.270 RC= 1.270

CONTINUUM STATE PARAMETERS V= 43.314 R= 1.250 A= 0.650 VS= 0.0 RS= 1.250 B= 0.650

W= 0.0 RI= 1.250 AI= 0.650 WS= 7.500 RIS= 1.250 BI= 0.700

VSO= 5.500 RSO= 1.250 ASO= 0.650 RC= 1.250

OPTICAL POTENTIAL ROSEN TYPE

2D 5/2 ER= 5.4880 EGAM= 37.2624 VB= 56.00

L1= 4.	J1= 4.5	RQ= 0.4045 01	IQ= 0.594E 01	Q2= 0.596E 02	Z2=	14.2857
L1= 4.	J1= 3.5	RQ= 0.933E 01	IQ= 0.636E 01	Q2= 0.137E 03	Z2=	1.1429
L1= 2.	J1= 2.5	RQ= 0.275E 01	IQ=-0.697E 01	Q2= 0.548E 02	Z2=	6.8571
L1= 2.	J1= 1.5	RQ= 0.246E 01	IQ=-0.873E 01	Q2= 0.822E 02	Z2=	1.7143
L1= 0.	J1= 0.5	RQ=-0.679E 01	IQ=-0.390E 01	Q2= 0.486E 02	Z2=	6.0000

SIGMA(2., 2.5)= 0.991E 01

1H 1/2 ER= 3.8720 EGAM= 35.6404 VB= 56.00

L1= 7.	J1= 7.5	RQ= 0.570E 01	IQ=-0.409E 01	Q2= 0.113E 03	Z2=	25.9481
L1= 7.	J1= 6.5	RQ=-0.233E 01	IQ=-0.233E 02	Q2= 0.554E 03	Z2=	0.5874
L1= 5.	J1= 5.5	RQ=-0.755E 01	IQ=-0.264E 01	Q2= 0.640E 02	Z2=	14.6853
L1= 5.	J1= 4.5	RQ=-0.137E 02	IQ=-0.693E 00	Q2= 0.114E 03	Z2=	0.6993
L1= 3.	J1= 3.5	RQ=-0.427E 00	IQ= 0.281E 01	Q2= 0.906E 01	Z2=	18.1818

SIGMA(5., 5.5)= 0.1[illegible] 02

3S 1/2 ER= 3.0750 EGAM= 34.8436 VB= 56.00

L1= 2.	J1= 2.5	RQ=-0.437E 01	IQ= 0.325E 01	Q2= 3.819E 02	Z2=	6.0000
L1= 2.	J1= 1.5	RQ=-0.324E 01	IQ= 0.135E 02	Q2= 0.121E 03	Z2=	4.0000

SIGMA(0., 0.5)= 0.334E 01

2D 3/2 ER= 2.0503 EGAM= 34.7744 VB= 56.00

L1= 4.	J1= 3.5	RQ= 0.323E 01	IQ= 0.614E 01	Q2= 0.123E 03	Z2=	10.2857
L1= 2.	J1= 2.5	RQ= 0.172E 01	IQ=-0.373E 01	Q2= 0.360E 02	Z2=	1.7143
L1= 2.	J1= 1.5	RQ= 0.151E 01	IQ=-0.736E 01	Q2= 0.565E 02	Z2=	4.0000
L1= 0.	J1= 0.5	RQ=-0.235E 01	IQ=-0.255E 01	Q2= 0.234E 02	Z2=	4.0000

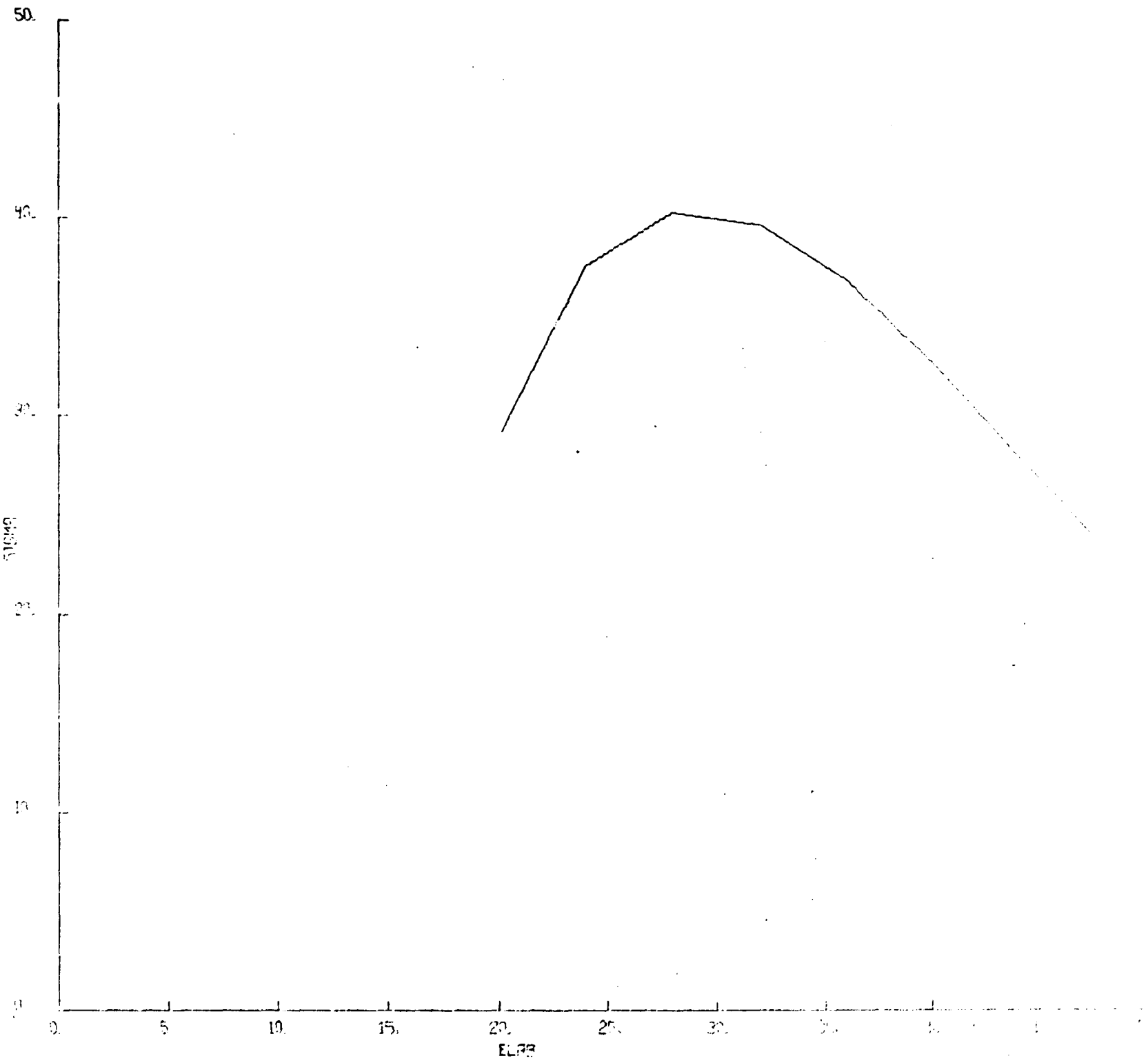
SIGMA(2., 1.5)= 0.[illegible] 01

SIGMA TOT(32.00)= 0.[illegible] 02

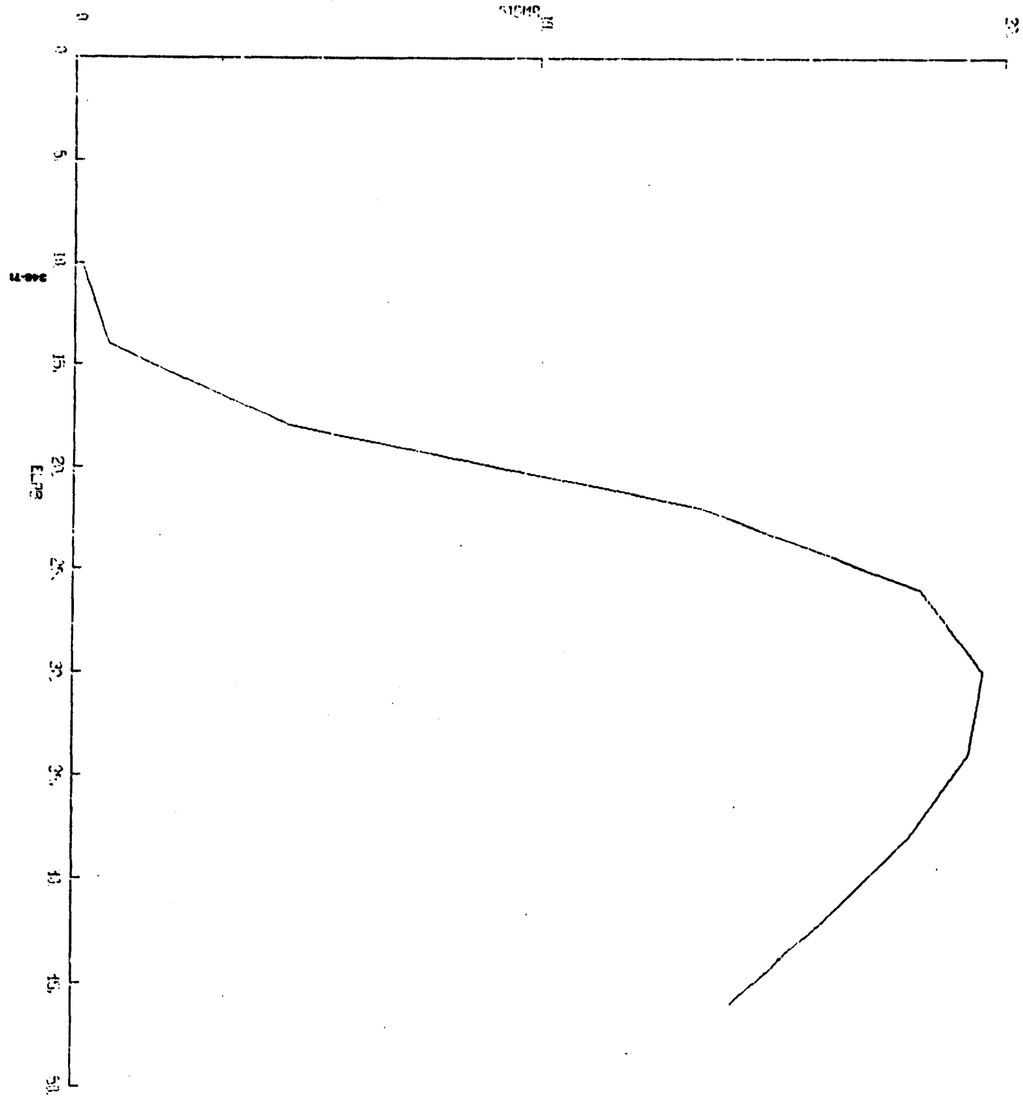
APPENDIX 3

TEST RUN PLOTS

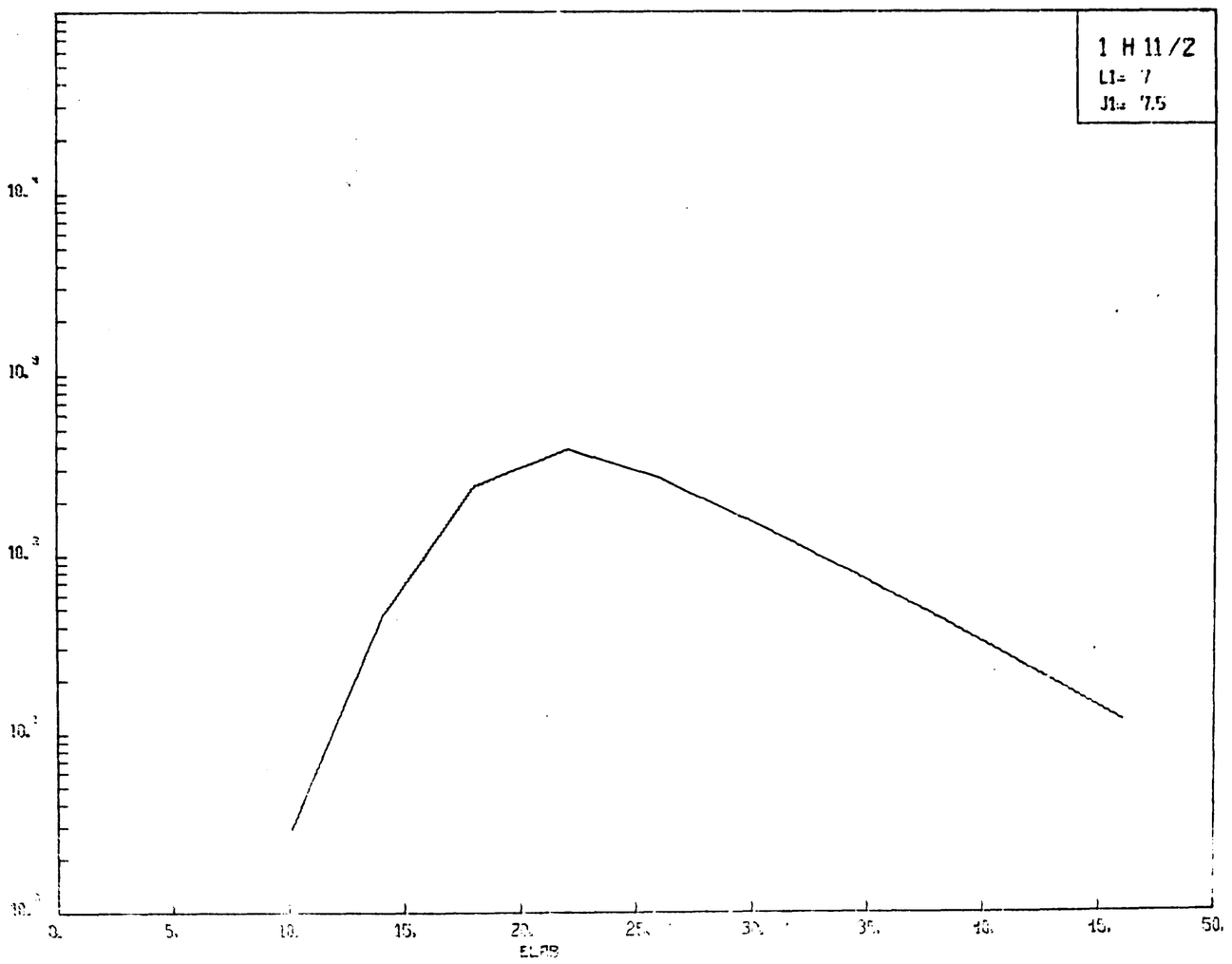
CE-142 (P,GAM) SIGMA(E)



CE-142 SIGMA 11/2 **KISS**



CE-142 Q2(H 11/21 **KISS**

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