Spin-Flip in $^{12}$C ($p, p'$) $^{12}$C Near the 9.14 MeV Doublet

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SPIN-FLIP IN $^{12}\text{C} (p,p')^{12}\text{C}$ NEAR THE 9.14 MEV DOUBLET

by

John Ambani Muhanji

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
December 1974
ACKNOWLEDGEMENTS

The author wishes to thank Professor E. M. Bernstein and Professor M. Soga for the generous time and devotion given to this project. Their willingness to help and answer questions is greatly appreciated. Also special thanks to Professor G. Hardie for his constructive criticism and valuable advice. Professor A. C. Dotson deserves credit for his encouragement during the course of this project.

Lastly, my great appreciation to the departments of physics and mathematics at Western Michigan University for providing the necessary hardware pertinent to this project.

John Ambani Muhanji
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SPIN-FLIP IN $^{12}$C ($p,p'$) $^{12}$C NEAR THE
9.14 MEV DOUBLET.

Western Michigan University, M.A., 1974
Physics, nuclear

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CHAPTER I

INTRODUCTION

A new technique for determining spectroscopic information for nuclear resonance states has been developed by the Western Michigan University nuclear physics group. The method involves measurements of proton spin-flip differential cross sections in inelastic scattering along with inelastic differential cross sections on and near the resonance. These data are analyzed with a model-independent theoretical formulation to obtain the desired nuclear information. Bernstein et al. (Be 72) first demonstrated the applicability of this technique in a study of the 9.49 MeV 3/2- level in $^{13}$N. The results showed that this level in $^{13}$N decays to the 4.44 MeV 2+ state of $^{12}$C mainly by $p_{1/2}$ waves with little or no $p_{3/2}$ waves present. More recently (Be 73) the 8.9 MeV 1/2- level in $^{13}$N has been studied. In this case it was found that this level decays predominantly by $f_{5/2}$ waves to the 2+ first excited state of $^{12}$C.

In this thesis the spin-flip technique is used to investigate the 5/2- and the 7/2- doublet in the $^{12}$C plus proton system which occurs near a bombarding energy of 9.14 MeV. This case is more complex than the ones previously studied because there are two resonances involved and also because there will be interference between the two resonating amplitudes.
CHAPTER II

THEORY

Conservation of Angular Momentum and Parity

The general angular momentum diagram for a 0+ to a 2+ excitation process by protons (Ba 73) is shown in Figure I. Protons are inelastically scattered from a target nucleus $^{A}_{Z}X$ via an intermediate compound nuclear level $^{A+1}_{Z+1}Y$ of spin and parity $J^{\pi}$. The incident orbital and total angular momenta of the proton are denoted respectively by $\ell, J$ and the outgoing orbital and total angular momenta of the inelastically scattered proton are denoted by $\ell', J'$. Since, in this process, the total angular momentum and the parity have to be conserved, the following procedure is acceptable.

Conservation of angular momentum

The total angular momentum, $\vec{J}$, of the incident particle coupled to the spin angular momentum, $\vec{\ell}$, of the target nucleus determines the spin angular momentum, $\vec{J}$, of the compound nucleus. Thus:

$$\vec{J} + \vec{\ell} = \vec{J}$$

It is also known that the total angular momentum, $\vec{J}$, is formed from the orbital and spin angular momenta of the incident particle denoted as $\vec{\ell}$ and $\vec{S}$ respectively. Hence, $\vec{J} = \vec{\ell} + \vec{S}$. For a proton $S = \pm \frac{1}{2}$, therefore $J = \ell \pm \frac{1}{2}$.

Since $J = \frac{1}{2}$, inevitably $J = \ell \pm \frac{1}{2}$.
Figure I

Energy level diagram showing relevant angular momenta.
Using the same reasoning, the total angular momentum, $\vec{j}'$, of the outgoing proton coupled to the spin angular momentum, $\vec{J}_s$, of the residual nucleus must equal the total angular momentum, $\vec{J}$, of the compound nuclear state. Thus:

$$\vec{J} = \vec{j}' + \vec{J}_s$$

where

$$\vec{j}' = \vec{l}' + \vec{s}'$$

and since $\vec{j}' = \vec{1} \pm \frac{1}{2}$

$$\vec{J} = (\vec{l}' \pm \frac{1}{2}) + \vec{J}_s$$

**Conservation of parity**

If $\Pi$ is the parity of the state formed in the compound nucleus, then conservation of parity states that $\Pi$ is also the parity of the system consisting of the target nucleus and the incident proton.

Since the proton has positive parity and since the parity of the target ground state is also positive, it follows that $\Pi = (-1)^L$.

Similarly, the parity $\Pi$ of the compound nucleus must equal the parity $\Pi$ of the system consisting of the outgoing proton and residual nucleus. For a positive parity final state we must have $(-1)^L = (-1)^{\vec{l}'}$ and so $L$ and $L'$ are both even or both odd.

**Consequences of conservation of angular momentum and parity**

Consider a $\vec{J} = \pm \frac{5}{2}$ resonance. Since the parity is negative, only odd incident orbital angular momenta are allowed. Now, what are the possible values of incident orbital angular momenta allowed by conservation of angular momentum?

Since $j = \lambda \pm \frac{1}{2}$, $\frac{5}{2} = \lambda \pm \frac{1}{2}$.
The odd \( \mathcal{L} \) which satisfies this relation is \( \mathcal{L} = 3 \) \( (f_{3/2} \text{ wave}) \).

Also, since \((-1)^{\mathcal{L}} = (-1)^{\mathcal{L}'}\) only odd \( \mathcal{L}' \) conserve parity. The possible values of outgoing total angular momenta are obtained from

\[
\mathcal{J} = \overline{\mathcal{J}} + \overline{J_f}
\]

with \( \mathcal{J} = \frac{5}{2} \) and \( J_f = 2 \) in the case of interest here.

The possible values of \( \mathcal{J}' \) are

\[
\mathcal{J}' = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \frac{7}{2}, \frac{9}{2}
\]

the outgoing orbital angular momenta are given by

\[
\mathcal{J}' = \mathcal{J}' \pm \frac{1}{2}
\]

\[
\frac{1}{2} = \mathcal{J}' \pm \frac{1}{2} \quad \text{gives} \quad \mathcal{J}' = 1 \quad (f_{3/2} \text{ wave})
\]

\[
\frac{3}{2} = \mathcal{J}' \pm \frac{1}{2} \quad \text{gives} \quad \mathcal{J}' = 1 \quad (f_{3/2} \text{ wave})
\]

\[
\frac{5}{2} = \mathcal{J}' \pm \frac{1}{2} \quad \text{gives} \quad \mathcal{J}' = 3 \quad (f_{3/2} \text{ wave})
\]

\[
\frac{7}{2} = \mathcal{J}' \pm \frac{1}{2} \quad \text{gives} \quad \mathcal{J}' = 3 \quad (f_{3/2} \text{ wave})
\]

\[
\frac{9}{2} = \mathcal{J}' \pm \frac{1}{2} \quad \text{gives} \quad \mathcal{J}' = 5 \quad (f_{3/2} \text{ wave})
\]

To summarize the results for \( \mathcal{J}' = \frac{5}{2} \):

Incident proton: \( f_{3/2} \)

Outgoing proton: \( p_{3/2}, f_{3/2}, f_{3/2}, f_{3/2}, h_{3/2} \)

Consider a \( \mathcal{J}' = \frac{7}{2} \) resonance. Again the parity is negative so only odd \( \mathcal{L} \) contribute. Possible values for the incident orbital angular momenta are obtained from the relation

\[
\mathcal{J} = \mathcal{L} \pm \frac{1}{2}
\]

\[
\frac{7}{2} = \mathcal{L} \pm \frac{1}{2}
\]

Again the odd \( \mathcal{L} \) which satisfies this relation is \( \mathcal{L} = 3 \) \( (f_{3/2} \text{ wave}) \).

The possible \( \mathcal{L}' \) are also odd. The possible values of outgoing angular momenta are obtained from

\[
\mathcal{J} = \mathcal{J}' + J_f
\]
with $J = \frac{7}{2}$ and, again, $J_r = 2$ for the case of interest.

The possible values of $j'$ are

$$j' = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}, \frac{9}{2}, \frac{11}{2}$$

The outgoing orbital angular momenta are given by

$$j' = j'' + \frac{1}{2}$$

- $\frac{3}{2} = j'' + \frac{1}{2}$ gives $j'' = \frac{1}{2}$ \((p_{\frac{3}{2}} \text{ wave})\)
- $\frac{5}{2} = j'' + \frac{1}{2}$ gives $j'' = \frac{3}{2}$ \((p_{\frac{5}{2}} \text{ wave})\)
- $\frac{7}{2} = j'' + \frac{1}{2}$ gives $j'' = \frac{5}{2}$ \((p_{\frac{7}{2}} \text{ wave})\)
- $\frac{9}{2} = j'' + \frac{1}{2}$ gives $j'' = \frac{7}{2}$ \((p_{\frac{9}{2}} \text{ wave})\)
- $\frac{11}{2} = j'' + \frac{1}{2}$ gives $j'' = \frac{9}{2}$ \((p_{\frac{11}{2}} \text{ wave})\)

To summarize for $J^\Pi = \frac{7}{2}^-$ resonance:

Incident proton: $f_{\frac{7}{2}}$

Outgoing proton: $p_{\frac{3}{2}}, f_{\frac{5}{2}}, f_{\frac{7}{2}}, h_{\frac{9}{2}}, h_{\frac{11}{2}}$

Spin-Flip Measurements and Radiation Patterns

In a parity conserving process Schmidt et al. (Sc 64) have shown that in an inelastic proton scattering ($0^+ \rightarrow 2^+$) process the population of the magnetic substates of the residual nucleus are dependent on the spin change of the incident and outgoing proton. The nucleus is left in a $2^+$ state and in any of its substates $M_n = 0, \pm 1, \pm 2$.

It was A. Bohr (Bo 59) who established a mathematical relationship for the process. This relation which is simply based on conservation of angular momentum and parity is:

$$P_r e^{i\pi S_x} = P_f e^{i\pi S_x}$$

\begin{align*}
P_r & \equiv \text{Parity of incident particle-target nucleus system.} \\
S_x & \equiv \text{Spin projection of incident particle-target nucleus system.}
\end{align*}
\[ P_F \equiv \text{Parity of outgoing particle-residual nucleus system.} \]
\[ S_F \equiv \text{Spin projection of outgoing particle-residual nucleus system.} \]

The quantization axis is defined (see Figure II) as:
\[
\mathbf{Z} = \frac{\mathbf{K}_i \times \mathbf{K}_f}{|\mathbf{K}_i \times \mathbf{K}_f|}
\]

\( K_i \) - Incident particle wave vector
\( K_f \) - Outgoing particle wave vector

If \( P_i = P_f = + \)
\[ m_i = S_i \]
\[ S_f = m_f + M_h \]
then for a 0+ to 2+ excitation process by protons equation (1) becomes
\[ e^{i\pi (m_i + M_h - m_f)} = 1 \]

This means that \( m_i + M_h - m_f \) = even.

Therefore \( m_i = m_f \Rightarrow M_h = 0 \) \( \Rightarrow \) spin non-flip,
and \( m_i = -m_f \Rightarrow M_h = \text{even} + 2m_f \)
\[ = \text{even} + \text{odd} \]
\[ M_h = \pm 1 \Rightarrow \text{spin-flip.} \]

If consideration is given to the radiation pattern for \( \lambda = 2 \)
and \( M_h = 0, \pm 1, \pm 2 \), it is found that only \( \lambda = 2 \), \( M_h = \pm 1 \) radiation contributes to the intensity along the quantization axis as can be seen from Figure III.

Thus for a 0+ to a 2+ excitation process by protons spin-flip events can be detected by measuring coincidences between the inelastic protons and gamma-rays emitted perpendicular to the scattering plane.

This section follows closely that given by Baumann (Ba 73).
Figure II

Geometry for spin-flip measurements showing the axis of quantization.
Figure III

Radiation pattern diagrams for an electric quadrupole transition.
\[ l = 2, \quad m = \pm 2 \]
\[ l = 2, \quad m = \pm 1 \]
\[ l = 2, \quad m = 0 \]
Cross Sections

The differential cross section for scattering from a nucleus with spin angular momentum $\mathbf{I}_n$ and spin projection $M_n$ by a particle with spin projection $m_S$ to a state composed of a residual nucleus with spin $\mathbf{I}_n'$ spin projection $M_n'$ and an emitted particle with spin projection $m'_S$ is (Ch 72, Ba 73):

$$
\frac{d\sigma}{d\Omega} (\theta_P) = \frac{1}{2} \sum_{m_S, M_n, m'_S, M_n'} \left| \int \frac{\mathbf{I}_n}{m_S M_n} \frac{\mathbf{I}_n'}{m'_S M_n'} \left( \frac{\theta = \pi}{2} , \theta_P \right) \right|^2 \tag{2}
$$

where the scattering amplitude is (Ch 72, Ba 73):

$$
\int \frac{\mathbf{I}_n}{m_S M_n} \frac{\mathbf{I}_n'}{m'_S M_n'} \left( \frac{\theta = \pi}{2} , \theta_P \right) = \frac{4\pi}{k_n} \sum_{l, l', j, j', J, M} \langle \mathbf{l} S m_l | j m_j \rangle \langle \mathbf{l} S' m'_l | j' m'_{j'} \rangle \langle j \mathbf{I}_n m_j | M_n | J, M \rangle \chi \langle j \mathbf{I}_n' m'_{j'} | M_n' | J, M \rangle \chi \tag{2a}
$$

and the other quantities in the equation (2) above are:

$\theta_P \equiv \text{Scattering angle}$

$k_n \equiv \text{Incident particle wave-number}$

$l \equiv \text{Incident particle orbital angular momentum quantum number}$

$l' \equiv \text{Outgoing particle orbital angular momentum quantum number}$

$j \equiv \text{Incident particle total angular momentum quantum number}$

$j' \equiv \text{Outgoing particle total angular momentum quantum number}$

$J \equiv \text{Total angular momentum quantum number}$

$M \equiv \text{Total angular momentum projection quantum number}$
\( s \) \( \equiv \) Spin angular momentum quantum number of incident particle

\( m_\lambda \) \( \equiv \) Orbital angular momentum projection quantum number of the incident particle

\( m_s \) \( \equiv \) Spin angular momentum projection quantum number of the incident particle

\( m_{ij} \) \( \equiv \) Total angular momentum projection quantum number of the incident particle

\( S' \) \( \equiv \) Spin angular momentum quantum number of the outgoing particle

\( m'_\lambda \) \( \equiv \) Orbital angular momentum projection quantum number of the outgoing particle

\( m'_s \) \( \equiv \) Spin angular momentum projection quantum number of outgoing particle

\( m'_{ij} \) \( \equiv \) Total angular momentum projection quantum number of outgoing particle

In equations (2) and (2a) the summations can be taken over an appropriate range to reproduce the experimental data. In so doing, higher order partial waves are usually neglected. In the case of a 0+ to 2+ excitation process, \( I_n = M_n = 0 \) and \( I_n' = 2 \).

The resonating transition matrices are taken to be composed of a Breit-Wigner shape plus a background term. These are written as (Ch 72, Ba 73):

\[
T_{ij'j} = \frac{\sqrt{\Gamma}}{2(E-E_R) + i\frac{\Gamma}{2}} e^{i\alpha_{ij'j}} + R_{ij'j} e^{i\beta_{ij'j}}
\]  

(3)

\( \Gamma^e \) \( \equiv \) The elastic width of the resonating state in the compound nucleus

\( \Gamma^0 \) \( \equiv \) Partial width of decay for emitting a particle of angular momentum \( j' \)

\( \Gamma' \) \( \equiv \) The total width of the compound state
The resonance energy of the compound nuclear state

Resonating phase angle

Background phase angle

Background transition matrix amplitude

The pure background transition matrices are written as (Ch 72, Ba 73):

$$T_{lj^l'^j'} = R_{lj^l'^j'} e^{i\beta_{lj^l'^j'}}$$

For a narrow resonance all the quantities appearing in these matrices, apart from the energy, may be assumed energy independent and as such may be treated as adjustable parameters.

Since for non-spin flip $M_n' = 0, \pm 2$ and for spin-flip $M_n' = \pm 1$, the differential cross sections become (Ch 72, Ba 73):

$$\left[ \frac{d\sigma}{d\Omega} (\Theta_p) \right]^S = \frac{1}{2} \sum_{M_n' = \pm 1} \left[ \frac{f_{M_n', M_n', M_s, I_n = 0}}{m_s} \right]^2$$

$$\left[ \frac{d\sigma}{d\Omega} (\Theta_p) \right] = \frac{1}{2} \sum_{M_n' = 0, \pm 2} \left[ \frac{f_{M_n', M_n', M_s, I_n = 0}}{m_s} \right]^2 + \left[ \frac{d\sigma (\Theta_p)}{d\Omega} \right]^S$$

Since the $\Theta_p$ dependence can be expressed in spherical harmonics as (Me 61):

$$\sum_{\ell} (\ell, \Theta_p) = \sqrt{\frac{(2\ell+1)(\ell-1)!}{4\pi (\ell+1)!}} (-1)^m e^{im\Theta_p} \frac{P^m}{x} (\cos \frac{\pi}{2})$$

equations (5) and (6) can be written

$$\left[ \frac{d\sigma (\Theta_p)}{d\Omega} \right]^S = \frac{1}{K_p^2} \left\{ A_o^S + A_1^S P_1 (\cos \Theta_p) + A_2^S P_2 (\cos \Theta_p) + \cdots \right\}$$
The cross sections are then expressed in terms of $\Theta_p$ dependent Legendre polynomials times angle independent constants as shown above. If the number of partial waves participating in the reaction is known then the highest order polynomial in the expressions can be determined. Each Legendre coefficient may be expressed in terms of the quantities appearing in the various transition matrices. It should be observed, however, that these quantities are not all energy independent. In case of an isolated single level resonance, their energy dependence is expressed by the Breit-Wigner formula (Ch 72, Be 72):

\[
A_n^{(s)} = B_n^{(s)} + \frac{c_n^{(s)}}{1 + \chi^2} + \frac{D_n^{(s)}}{1 + \chi^2}
\]

\[
\chi \equiv \frac{2(E - E_R)}{\Gamma}, \quad \Gamma' \equiv \Gamma + \sum_j \gamma_j^{10}
\]

In general, it should be noted that the Legendre coefficients which appear in the cross section relations are not linearly independent.

For two resonances at the same energy the energy dependence of the Legendre coefficients is more complicated than for the single level case. For the $5/2^-$, $7/2^-$ doublet in $^{13}$N, which is of interest here, it was found from elastic scattering measurements (Be 68) that the two resonance energies are the same or within a few keV of each other. This result is verified in the present work; therefore, for the relations given below the two resonance energies are assumed to be the same.
If the $5/2^-$ level and the $7/2^-$ level transition matrices are designated as $T_1$ and $T_2$, respectively, and if background transition matrices are designated as $T_0$, it then follows (Eq. 74) that:

$$T_1 = B_1 e^{i\beta_1} + C_1 \frac{1}{(E-E_R) + i\frac{\gamma}{2}} e^{i\alpha_1}$$

$$T_2 = B_2 e^{i\beta_2} + C_2 \frac{1}{(E-E_R) + i\frac{\gamma}{2}} e^{i\alpha_2}$$

$$T_0 = B_0 e^{i\beta_0}$$

Where the first terms in $T_1$ and $T_2$ are the background terms and the second terms are the resonating terms.

If $X_1 = \frac{2(E-E_R)}{\Gamma_1}$ and $X_2 = \frac{2(E-E_R)}{\Gamma_2}$

$$T_1 = B_1 e^{i\beta_1} + \frac{2C_1}{\Gamma_1} \left( \frac{1}{X_1+i} \right) e^{i\alpha_1}$$

$$T_2 = B_2 e^{i\beta_2} + \frac{2C_2}{\Gamma_2} \left( \frac{1}{X_2+i} \right) e^{i\alpha_2}$$

$$|T_1|^2 = B_1^2 + 2B_1 \frac{2C_1}{\Gamma_1} \cos(\alpha_1-\beta_1) \frac{X_1}{1+X_1^2} + \left( \frac{2C_1}{\Gamma_1} \right)^2 + 2B_1 \frac{2C_1}{\Gamma_1} \sin(\alpha_1-\beta_1) \frac{1}{1+X_1^2}$$

$$|T_2|^2 = B_2^2 + 2B_2 \frac{2C_2}{\Gamma_2} \cos(\alpha_2-\beta_2) \frac{X_2}{1+X_2^2} + \left( \frac{2C_2}{\Gamma_2} \right)^2 + 2B_2 \frac{2C_2}{\Gamma_2} \sin(\alpha_2-\beta_2) \frac{1}{1+X_2^2}$$

$$R\left(T_0T_1^*\right) = B_0 B_1 \cos(\beta_0-\beta_1) + B_0 \frac{2C_1}{\Gamma_1} \cos(\alpha_1-\beta_0) \frac{X_1}{1+X_1^2} + B_0 \frac{2C_1}{\Gamma_1} \sin(\alpha_1-\beta_0) \frac{1}{1+X_1^2}$$

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In these expressions $R$ means take the real part of the complex expression.

The coefficients of the even order Legendre polynomials which appear in the cross section relations, equations (7) and (8), contain linear combinations of all of the products of the $T$ matrix elements given above (So 74). Since the quantities of interest are the resonating amplitudes and since only the even order Legendre coefficients contain the squares of these amplitudes, the odd order coefficients are not considered here.

By making a linear combination of all of the terms in the above products of matrix elements which have the same energy dependence, one can write a general form for the even order Legendre coefficients. This general form can be written
\[ A_n = B_n + \frac{E_n}{1 + X_1^2} + \frac{F_n}{1 + X_2^2} + \frac{C_n X_1}{1 + X_1^2} + \frac{D_n X_2}{1 + X_2^2} + \frac{1}{(1 + X_1^2)(1 + X_2^2)} \left[ H_n \left( i + X_1 X_2 \right) + G_n \left( X_1 - X_2 \right) \right] \] (15)

The quantities B, E, F, C, D, G and H are complicated combinations of the amplitudes and phase angles of the T matrix elements. For narrow levels like the ones considered here these quantities can be taken to be independent of energy. (Actually, the background term, B, is allowed a slowly varying linear energy dependence.) In this case all of the energy dependence in this equation is contained in the parameters X_1 and X_2.
CHAPTER III

EXPERIMENTAL METHOD

The block diagram in Figure IV shows the electronics used. With the exception of the addition of a constant fraction discriminator in place of the fast integral discriminator the experimental method and set up was similar to the one used by Baumann (Ba 73).

Beams of 8.904 to 9.403 MeV protons were produced that impinged on 5 Kev thick (at 9 Mev) natural carbon. The beam energy was determined by a 90° analyzing magnet calibrated by Parrott (Pa 71). The beam currents ranged from 12 to 110 nano-amps.

Gamma rays that were emitted normal to the scattering plane were detected by a NaI (Tl) crystal while the protons were detected by a surface barrier detector in the scattering plane.

Although spin-flip events imply coincidence between inelastically scattered protons and the de-excitation gamma rays, it is not unusual to monitor coincidence events that are not from spin-flip but due to accidentals. This is seen in the coincidence spectrum (Figure V) since the elastic peak could only occur due to accidental coincidences.

Shown in Figure VI is a time to pulse height converter (TPHC) spectrum. During the measurements the actual time resolution used was approximately 2.5 ns. The measurements for determining inelastic and inelastic spin-flip differential cross sections were made at 14 or 15 angles that ranged from 30° to 165° in the laboratory.
Figure IV

Block diagram of electronics used to detect coincidences between inelastically scattered protons and de-excitation gamma rays.
DASHED LINE IS FOR CHECKING APPROPRIATE WINDOW ON GAMMA RAY SPECTRUM
Figure V

Coincidence and non-coincidence spectra for $^{12}\text{C} \, (p,p') \, ^{12}\text{C}$. 

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$^{12}\text{C} + \text{protons}$

Ungated Spectrum
$E_p = 9.139 \text{ MeV}$
$\theta_{\text{Lab}} = 52^\circ$

COINCIDENCE SPECTRUM

$X_5 \text{ ELASTIC}$

COUNTS $\times 10^3$

CHANNEL NUMBER

110 120 130 140 280 290 300

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Figure VI

A typical time to pulse height converter spectrum for $^{12}\text{C} \ (p,p')^{12}\text{C}$. 
Energies were taken near and on the $5/2^-$, $7/2^-$ doublet and ranged from 8.904 to 9.403 MeV in the laboratory. To ensure that the inelastic cross section was correct, the inelastic yield was normalized and found in agreement with cross sections measured by Barnard et al. (Ba 66).

To get true coincidences, the accidental coincidences were subtracted from the total inelastic coincidences. The number of accidentals was determined by multiplying the inelastic counts by the ratio of the purely accidental elastic counts in the coincidence spectrum to the total elastic counts. In general the accidental coincidences were less than 10% of the true coincidences.

There is a relationship between the number of the coincidences, $N(\Theta)$, and the spin-flip probability, $S(\Theta)$. This (Sc 64, Ba 73) is given by:

$$S(\Theta) = \frac{8\pi}{5} \frac{N(\Theta)}{\epsilon \Omega}$$

where $\epsilon \Omega$ is the product of the gamma ray detector efficiency and solid angle. The constant factor $\frac{8\pi}{5}$ accounts for the fact that all spin-flip events do not emit radiation normal to the reaction plane.

Corrections to the spin-flip probabilities for the effects of the finite solid angles were made using derivations by Kolata et al. (Ko 69).

The proton detector was assumed 100% efficient. The gamma ray detector efficiency was the same as determined by Baumann (Ba 73). The uncertainty in the gamma detector efficiency is ± 10%.

The inelastic differential cross sections have an uncertainty of 5%; the uncertainty in the spin-flip cross sections varied

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according to the statistical errors in the coincidence counts.
CHAPTER IV

RESULTS AND DISCUSSION

It has already been established (see equations 7, 8) that the spin-flip and inelastic differential cross sections can be expressed as Legendre polynomial expansions. The experimentally determined cross sections were individually fit to determine the Legendre polynomial coefficients at each energy point using a computer routine (We 72). These coefficients, in units of mb/sr, are given in Tables 1 and 2 for the inelastic and spin-flip cross sections, respectively.

Figure VII shows typical angular distributions for inelastic scattering and spin-flip inelastic scattering. The solid curves are the Legendre polynomial fits to the data.

Figures VIII and IX show the energy dependence of the even order Legendre coefficients. The solid curves shown in these figures are fits to the experimental data. The fits were obtained using a computer search routine, JUNGLE (given in Appendix I), which reproduced the data using the energy dependence given by equation 15. Unfortunately, it is possible to obtain fits to the data with a number of different parameter sets. The values of the parameters corresponding to the fits shown in Figures VIII and IX are given in Tables 3 and 4.

Since the Legendre polynomial fits to the angular distributions do not require polynomials higher than order 4 (So 74), it is rather certain that little or no f-wave decay is involved in the inelastic
Table 1

Values of the Legendre coefficients for the inelastic cross sections as a function of energy. The coefficients are given in millibarns per steradian.
<table>
<thead>
<tr>
<th>Lab Energy</th>
<th>( A_0 )</th>
<th>( A_1 )</th>
<th>( A_2 )</th>
<th>( A_3 )</th>
<th>( A_4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.901</td>
<td>20.013 ± 0.310</td>
<td>2.721 ± 0.742</td>
<td>16.003 ± 0.924</td>
<td>-0.540 ± 0.993</td>
<td>-4.162 ± 0.992</td>
</tr>
<tr>
<td>8.997</td>
<td>21.539 ± 0.337</td>
<td>4.198 ± 0.805</td>
<td>16.840 ± 1.011</td>
<td>-1.784 ± 1.088</td>
<td>-4.852 ± 1.069</td>
</tr>
<tr>
<td>9.074</td>
<td>22.960 ± 0.334</td>
<td>-0.186 ± 0.761</td>
<td>13.313 ± 0.999</td>
<td>-7.858 ± 1.132</td>
<td>-7.487 ± 1.174</td>
</tr>
<tr>
<td>9.100</td>
<td>26.336 ± 0.361</td>
<td>-5.008 ± 0.768</td>
<td>11.098 ± 1.028</td>
<td>-15.918 ± 1.248</td>
<td>-9.963 ± 1.365</td>
</tr>
<tr>
<td>9.126</td>
<td>38.547 ± 0.515</td>
<td>-8.807 ± 0.926</td>
<td>1.519 ± 1.351</td>
<td>-33.336 ± 1.801</td>
<td>-12.286 ± 2.012</td>
</tr>
<tr>
<td>9.133</td>
<td>42.877 ± 0.578</td>
<td>-8.683 ± 0.990</td>
<td>-3.978 ± 1.454</td>
<td>-31.415 ± 2.042</td>
<td>-14.473 ± 2.197</td>
</tr>
<tr>
<td>9.139</td>
<td>43.305 ± 0.585</td>
<td>-8.149 ± 1.013</td>
<td>-4.164 ± 1.469</td>
<td>-31.403 ± 2.083</td>
<td>-17.430 ± 2.213</td>
</tr>
<tr>
<td>9.152</td>
<td>38.335 ± 0.521</td>
<td>-5.217 ± 0.979</td>
<td>0.931 ± 1.375</td>
<td>-26.337 ± 1.882</td>
<td>-18.152 ± 1.977</td>
</tr>
<tr>
<td>9.165</td>
<td>31.839 ± 0.435</td>
<td>-4.698 ± 0.876</td>
<td>5.147 ± 1.186</td>
<td>-19.414 ± 1.549</td>
<td>-15.529 ± 1.650</td>
</tr>
<tr>
<td>9.230</td>
<td>20.684 ± 0.292</td>
<td>-2.577 ± 0.639</td>
<td>7.803 ± 0.799</td>
<td>-4.610 ± 0.978</td>
<td>-8.257 ± 1.054</td>
</tr>
<tr>
<td>9.292</td>
<td>18.608 ± 0.270</td>
<td>-1.248 ± 0.607</td>
<td>8.174 ± 0.736</td>
<td>-1.225 ± 0.884</td>
<td>-8.042 ± 0.931</td>
</tr>
<tr>
<td>9.400</td>
<td>17.644 ± 0.264</td>
<td>-0.499 ± 0.618</td>
<td>10.103 ± 0.733</td>
<td>1.643 ± 0.847</td>
<td>-7.064 ± 0.877</td>
</tr>
</tbody>
</table>
Table 2

Values of the Legendre coefficients for the spin-flip inelastic cross sections as a function of energy. The coefficients are given in millibarns per steradian.
<table>
<thead>
<tr>
<th>Lab. Energy</th>
<th>Spin-Flip</th>
<th>(A_0)</th>
<th>(A_1)</th>
<th>(A_2)</th>
<th>(A_3)</th>
<th>(A_4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.909</td>
<td>8.900</td>
<td>5.237 ± 0.142</td>
<td>-2.801 ± 0.365</td>
<td>-3.874 ± 0.380</td>
<td>2.422 ± 0.456</td>
<td>-0.709 ± 0.455</td>
</tr>
<tr>
<td>9.007</td>
<td>9.097</td>
<td>4.597 ± 0.141</td>
<td>-2.879 ± 0.375</td>
<td>-3.873 ± 0.375</td>
<td>0.455 ± 0.516</td>
<td>-1.810 ± 0.560</td>
</tr>
<tr>
<td>9.100</td>
<td>9.100</td>
<td>5.564 ± 0.154</td>
<td>-2.730 ± 0.410</td>
<td>-3.842 ± 0.410</td>
<td>0.512 ± 0.516</td>
<td>-1.850 ± 0.560</td>
</tr>
<tr>
<td>9.126</td>
<td>9.126</td>
<td>8.457 ± 0.200</td>
<td>-6.291 ± 0.521</td>
<td>-3.820 ± 0.521</td>
<td>-5.110 ± 0.717</td>
<td>-8.118 ± 0.785</td>
</tr>
<tr>
<td>9.133</td>
<td>9.130</td>
<td>10.353 ± 0.269</td>
<td>-4.050 ± 0.691</td>
<td>-7.506 ± 0.975</td>
<td>-7.163 ± 0.848</td>
<td>-2.924 ± 1.083</td>
</tr>
<tr>
<td>9.139</td>
<td>9.139</td>
<td>12.227 ± 0.239</td>
<td>-1.322 ± 0.610</td>
<td>-7.303 ± 0.713</td>
<td>-3.803 ± 0.988</td>
<td>-9.255 ± 1.083</td>
</tr>
<tr>
<td>9.146</td>
<td>9.146</td>
<td>10.122 ± 0.273</td>
<td>-3.181 ± 0.541</td>
<td>-3.933 ± 0.756</td>
<td>-8.188 ± 0.976</td>
<td>-10.278 ± 0.843</td>
</tr>
<tr>
<td>9.152</td>
<td>9.152</td>
<td>8.797 ± 0.208</td>
<td>-3.855 ± 0.541</td>
<td>-3.855 ± 0.541</td>
<td>1.688 ± 0.590</td>
<td>-6.321 ± 0.628</td>
</tr>
<tr>
<td>9.165</td>
<td>9.165</td>
<td>6.137 ± 0.168</td>
<td>-4.855 ± 0.363</td>
<td>-4.297 ± 0.447</td>
<td>3.324 ± 0.447</td>
<td>-2.356 ± 0.461</td>
</tr>
<tr>
<td>9.200</td>
<td>9.200</td>
<td>4.870 ± 0.137</td>
<td>-4.870 ± 0.137</td>
<td>-5.065 ± 0.366</td>
<td>-5.555 ± 0.297</td>
<td>1.993 ± 0.355</td>
</tr>
<tr>
<td>9.400</td>
<td>9.400</td>
<td>3.742 ± 0.108</td>
<td>-3.742 ± 0.108</td>
<td>-6.555 ± 0.297</td>
<td>1.993 ± 0.355</td>
<td>-2.532 ± 0.372</td>
</tr>
</tbody>
</table>
Angular distributions for inelastic scattering and spin-flip inelastic scattering near 5/2− and 7/2− doublet in $^{13}$N. The solid curves represent Legendre polynomial fits to the experimental data. The energy of each angular distribution is listed in MeV next to the curve.
Figure VIII

Energy dependence of the even order Legendre coefficients for inelastic scattering. The solid curves represent fits to the experimental data.
Figure IX

Energy dependence of the even order Legendre coefficients for spin-flip inelastic scattering. The solid curves represent fits to the experimental data.
Table 3

Parameters for fits of equation 15 to the experimentally determined energy dependence of the even order Legendre polynomial coefficients for inelastic scattering. Values are given in mb/sr. The background (B) is given as a linearly varying function of energy.
<table>
<thead>
<tr>
<th>Table 3</th>
<th>Inelastic</th>
<th>Legendre Coefficient</th>
<th>( E = 9.139 \text{ MeV} )</th>
<th>( \Gamma_2 = 0.088 \text{ MeV} )</th>
<th>( 1^2 \text{C} ) (p,p') ( 1^2 \text{p} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( J_1 = \frac{1}{2}^- )</td>
<td>( J_2 = \frac{3}{2}^- )</td>
<td>( F )</td>
<td>( C )</td>
<td>( D )</td>
<td>( E )</td>
</tr>
<tr>
<td>( A_0 )</td>
<td>14.725</td>
<td>11.051</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>( A_2 )</td>
<td>-12.485</td>
<td>2.799</td>
<td>-5.50</td>
<td>9.399</td>
<td>-0.041</td>
</tr>
<tr>
<td>( A_4 )</td>
<td>9.450</td>
<td>0.0</td>
<td>0.005</td>
<td>-22.148</td>
<td>-10.730</td>
</tr>
</tbody>
</table>

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Parameters for fits of equation 15 to the experimentally determined energy dependence of the even order Legendre polynomial coefficients for spin-flip inelastic scattering. (See the caption for Table 3.)

Table 4
Table 4

\[ {}^{12}\text{C} (p,p') {}^{12}\text{C} \]

<table>
<thead>
<tr>
<th>Spin-Flip</th>
<th>( J^\pi = \frac{5}{2}^- )</th>
<th>( J^\pi = \frac{7}{2}^- )</th>
<th>( \Gamma_i = 0.33 \text{MeV} )</th>
<th>( \Gamma_i = 0.83 \text{MeV} )</th>
<th>( E_{R_1} = E_{R_2} = 9.139 \text{MeV} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Lambda_0^s )</td>
<td>7.258</td>
<td>-0.178</td>
<td>-0.919</td>
<td>1.40</td>
<td>0.0</td>
</tr>
<tr>
<td>( \Lambda_2^s )</td>
<td>-10.015</td>
<td>-1.071</td>
<td>0.0997</td>
<td>3.988</td>
<td>0.0</td>
</tr>
<tr>
<td>( \Lambda_4^s )</td>
<td>6.785</td>
<td>0.0</td>
<td>10.719</td>
<td>0.0</td>
<td>-12.039</td>
</tr>
</tbody>
</table>
decay of $\frac{7}{2}^-$ level. Therefore this state decays to the $2^+$ state in $^{12}\text{C}$ by pure $\frac{3}{2}^+$ waves.

Also, the presence of 4th order polynomials with no f-wave decay from the $\frac{7}{2}^-$ level implies that f-wave inelastic decay from the $\frac{5}{2}^-$ level is present (So 74).

In view of the ambiguity in fitting the energy dependence of the even order coefficients, it appears that it may not be possible to obtain the relative intensities for the various partial waves in the inelastic decay of the $\frac{5}{2}^-$ level.

The fits to the energy dependence of the coefficients were obtained with coincident values for the resonance energies ($E_{R_1} = E_{R_2} = 9.139 \text{ MeV}$) and values for the total widths of the levels of $\Gamma_1 = .033 \text{ MeV}$ and $\Gamma_2 = .088 \text{ MeV}$. These results are in excellent agreement with determinations made from elastic scattering measurements (Be 68).

In summary, the present results support resonance parameters for the $\frac{5}{2}^- - \frac{7}{2}^-$ doublet in $^{13}\text{N}$ - obtained from elastic scattering measurements and strongly indicate that the inelastic decay of the $\frac{7}{2}^-$ level is only by $\frac{3}{2}^+$ waves while the inelastic decay of the $\frac{5}{2}^-$ level does involve f-waves.
BIBLIOGRAPHY


So 74 M. Soga, private communication.

We 72 Computer routine obtained from J. J. Ramirez; written by H. R. Weller, University of Florida.

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APPENDIX I
APPENDIX I

This appendix gives a listing of the computer search routine JUNGLE which was used to obtain fits to the energy dependence of the even order Legendre polynomials. The energy dependence is parameterized according to equation 15.
C PROGRAM TO FIT BRIET-WIGNER AND MODIFIED BRIET-WIGNER FUNCTIONS

DIMENSION E(50),SIGEXP(52),SIGEX(52),SIGMA(50),ERR(50)
DIMENSION X1(52),X2(52)
COMMON E,SIGEXP,SIGEX,SIGMA,ERR,NE,EMPL,FMLP,CD,GW,WDT1
COMMON WDT2,ERES1,ERES2,CHLST,CONST
COMMON CHLAST,CHISQR,CH,COUNT,CNTMAX,G,DELO,NSET,NSERCH
READ(5,21)NSET
1 READ(5,12)E1,E2,E3,E4,E5
READ(5,20)(E(I),SIGEXP(I),SIGEX(I),SIGMA(I),ERR(I))
READ(5,100)
10 FORMAT(3F12.5,3I5)
20 FORMAT(3F12.5)
30 FORMAT(4F12.5,1I5)
40 FORMAT(4F13.5)
C=0
COUNT=0
WRITE(6,120)
120 FORMAT(3C10.3.5X,*0=*,F10.4,5X,'EMPL=',F10.5,5X,'WDT1=',F10.5,5X,'ERES1=',F10.5,5X,'CHI SQUARE=',F10.5)
IF(CHISQR-CHLAST)2202.2022,2702,2022
CALL CMSR
WRITE(6,122)
2202 FORMAT(CM10.3.5X,*0=*,F10.4,5X,'EMPL=',F10.5,5X,'WDT1=',F10.5,5X,'ERES1=',F10.5,5X,'CHI SQUARE=',F10.5)
RETURN PARAMETERS TO PREVIOUS VALUES
2203 IF(M1)2201,2202,2203
2201 ERES1=ERES1/CHG1
2202 IF(M2)2204,2205,2206
2204 IF(M3)2207,2208,2209
2205 WDT1=2047/CMG3
2206 IF(M4)2209,2210,2211
2209 EMLP=EMPL/CMG4
2210 IF(M5)2212,2213,2214
2212 IF(M6)2215,2216,2217
2215 CD=CD/CMG6
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20084 IF (M7 .GT. 20255, 20266, 20255)
20085 WDTM2=WDTM2/CHG7
20266 IF (M8 .GT. 20267, 20268, 20257)
20267 FPL=FPL/CHG8
20268 IF (M9 .GT. 20279, 20290, 20259)
20290 G=CHG9
20292 IF (M12 .GT. 20301, 20302, 20291)
20291 W=CHG12
20292 CONTINUE
20300 IF (Q-QMN) 5020, 5200, 3000
C SEARCH ROUTINE
3000 XNR=X.2
3001 ERES1=ERES1-.2001
CALL CH19
3002 IF (M2 .GT. 3003, 3004, 3002)
3003 C=C+.065
3004 CALL CH19
3005 CH2=CHISOR-CH
3006 IF (C13 .GT. 3131, 3312, 3006)
3132 CHM=CH2
3133 XNR=XNORM+CH2.02
3204 IF (M3 .GT. 3205, 3306, 3204)
3205 WOTH=WOTH1-.22
CALL CH20
3206 IF (M4 .GT. 3207, 3208, 3206)
3207EMPL=EMPL+.025
CALL CH20
3208 EMPL=EMPL-.025
3209 CHM=CHISOR-CH
3306 IF (EMPL .GT. 3307, 3308, 3306)
3307 CH4=CH4
3308 XNR=XNORM+CH4.02
3227 IF (M5 .GT. 3228, 3329, 3227)
3228 ERES2=ERES2-.2301
CALL CH20
3229 ERES2=ERES2-.2301
CH5=CHISOR-CH
3230 XNR=XNORM+CH5.02
3327 IF (M6 .GT. 3328, 3329, 3327)
3328 D=D-.025
CALL CH20
3329 D=D+.025
3330 CH6=CHISOR-CH
3331 IF (D1 .GT. 3332, 3333, 3331)
3332 CH6=CH6
3333 XNR=XNORM+CH6.02
3334 IF (M7 .GT. 3335, 3336, 3334)
3335 WOTH=WOTH2-.22
CALL CH20
3336 WOTH=WOTH2-.22
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CH7*CHISOR-CH
XNORM=XNORM+CH7**2
30077 IF (M8) 32279, 32379, 32278
30078 FMPL=FMPL-.025
CALL CH150
FMPL=FMPL-.025
CHS=CHISOR-CH
IF (FMPL) 32179, 32180, 32180
30179 CH8=C48
30180 XNORM=XNORM+CH8**2
30279 IF (M9) 32280, 32281, 32282
30283 G=+.025
CALL CH15C
G=+.025
CH9=CHISOR-CH
IF (G) 32984, 32985, 32985
3084 CH9=C49
3285 XNORM=XNORM+CH9**2
30881 IF (M10) 32882, 32883, 32882
30882 M=+.375
CALL CH15D
W=+.035
CH10=CHISOR-CH
IF (M) 32181, 32182, 32182
30181 CH12=C12
30182 XNORM=XNORM+CH12**2
30283 CONTINUE
IF (M1) 32012, 3211, 3210
3010 CHG1=1.2-O*C11*(SORT(CH1**2))/XNORM
ERES1=ERES1+CH1
3011 IF (M2) 32112, 32113, 32112
3012 CHG2=1.2-O*C12*(SORT(CH2**2))/XNORM
ERES2=ERES2+CH2
3013 IF (M3) 32134, 3215, 3214
3014 CHG3=1.2-O*C13*(SORT(CH3**2))/XNORM
WDTH1=WDTH1*CH3
3015 IF (M4) 32156, 3217, 3216
3016 CHG4=1.2-O*C14*(SORT(CH4**2))/XNORM
FMPL=FMPL+CH4
3017 IF (M5) 32168, 3219, 3218
3018 CHG5=1.2-O*C15*(SORT(CH5**2))/XNORM
ERES2=ERES2+CH5
3019 IF (M6) 32200, 3221, 3220
3020 CHG6=1.3-O*C16*(SORT(CH6**2))/XNORM
D=0*CH6
3021 IF (M7) 3222, 3223, 3222
3022 CHG7=1.3-O*C17*(SORT(CH7**2))/XNORM
WDTH2=WDTH2+CH7
3023 IF (M8) 3224, 3225, 3224
3024 CHG8=1.2-O*C18*(SORT(CH8**2))/XNORM
FMPL=FMPL+CH8
3025 IF (M9) 3226, 3227, 3226
3026 CHG9=1.3-O*C19*(SORT(CH9**2))/XNORM
F=0*CH9
3027 IF (M10) 3228, 3229, 3228
3028 CHG10=1.3-O*C10*(SORT(CH10**2))/XNORM
W=0**517
3029 CONTINUE
CH10=CH10
NCOUNT=NCOUNT+1
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SUBROUTINE CHISO
DIMENSION E(50),SIGEXP(50),OSIGEX(50),SIGMA(50),ERR(50)
DIMENSION X1(50),X2(50)
COMMON E.SIGEXP.OSIGEX.SIGMA.ERR.NE.EMPL.FMPL.C.D.G.H.WDTH1
COMMON WDTH2.ERESi.ERES2.A.CONST
COMMON CHLAST,CHISQR.CH,NCOUNT,NCTMAX,G,QMIN.DELQ.NSET.NSEARCH
CHISQR=3.0
DO 10 I=1,NE
X1(I)=2.0*(E(I)-ERES1)/WDTH1
X2(I)=2.0*(E(I)-ERES2)/WDTH2
SIGMA(I)=E(I)*CONST*EMPL/(1+X1(I)**2)+FMPL/(1+X2(I)**2)
1=CONST/(1+X1(I)**2)*X2(I)/(1+X2(I)**2)
1=SIGMA(I)*(1+X1(I)**2)*X2(I)/(1+X2(I)**2)
1=(1+X1(I)**2)*X2(I)/(1+X2(I)**2))**2
CONTINUE
IF(NSEARCH)11,21,11
11 CONTINUE
ERR(I)=SIGMA(I)-SIGEXP(I)
20 CHISQR=CHISQR*(ERR(I)/OSIGEX(I))**2
21 CONTINUE
RETURN
END

SUBROUTINE OUTPUT
DIMENSION E(50),SIGEXP(50),OSIGEX(50),SIGMA(50),ERR(50)
DIMENSION X1(50),X2(50)
COMMON E.SIGEXP.OSIGEX.SIGMA.ERR.NE.EMPL.FMPL.C.D.G.H.WDTH1
COMMON WDTH2.ERESi.ERES2.A.CONST
COMMON CHLAST,CHISQR.CH,NCOUNT,NCTMAX,G,QMIN.DELQ.NSET
WRITE(6,10)NCOUNT
10 FORMAT(///'NUMBER OF SEARCHES=',13//)
WRITE(6,20)
20 FORMAT(12X,'FINAL PARAMETERS//')
WRITE(6,30)EMPL,OTHI.ERES1.C.FMPL,WDT1,ERES2,D.G.H
30 FORMAT(8X,'EMPL=',F12.5,6X,'WDT1=',F13.5,6X,'ERES1=',F14.5,5X
1,'C=',F11.5,5X,'FMPL=',F10.5,5X,'ERES2=',F10.5,5X,'D=',F11.5,5X,'G=',F11.5,5X,'H=',F11.5,5X)
WRITE(6,40)CHISQR,G
40 FORMAT(17X,'CHISQ SQUARE=',F12.3,'STEP SIZE=',F13.4//)
WRITE(6,52)
50 FORMAT(17X,'ENERGY',18X,'SIGMACALC',12X,'SIGMAEXP',11X,'DIFF'
1,13X,'DELTA SIGMA EXP')
WRITE(6,62)(SIGMA(I),I=1,NE)
60 FORMAT(6X,F12.5,9X,F10.5,8X,F10.5,5X,F10.5,11X,F10.5)
WRITE(6,70) A, CONST
70 FORMAT(/10X,'BACKGROUND=',F10.3,'*E(1)=',F10.3//)
CALL SDRAW(E, SIGMA, SIGEXP, N)
CONTINUE
RETURN
END

***** *** ***** *** *****

***** *** ***** *** *****

SUBROUTINE SDRAW(X,Y,YY,NPTS)
DIMENSION X(52), Y(52), YY(52), LINE(122), XX(52), YYL(50)
DATA IBLANK, IDOT, IXX, IPLUS, ISAME, IXX/1H, IH, IHT, IHE, IH=, IH* /
WRITE(6,1)
1 FORMAT(IHI,62X,'CROSS SECTION (MB/SP)'),
DO 101 J=1,122
101 LINE(J)=IDOT
WRITE(6,123)LlNE
DO 104 J=1,53104 IXX(J)=B
JKK=J-50
DO 105 J=1,NPTS
XX=(X(J)-XX(1))/X(NPTS)-X(1))*49.0-1.0
JJJ=IFIX(XX)
IF(JJJ-JKK)412,411,410
411 JJJ=JII+1
GO TO 410
412 JJJ=JJJ+2
410 JKK=JJJ
105 IX(JJJ)=0
YMIN=0.0
DO 10 1=1,NPTS
IF(Y(L).GE.2.0) GO TO 2
IF(YMIN-Y(L),GT.2.0)YMIN=Y(L)
CONTINUE
2 CONTINUE
DO 21 L=1,NPTS
IF(Y(L).GE.0.?) GO TO 21
IF(YMIN-YY(L),GT.2.0)YMIN=YY(L)
21 CONTINUE
120 YMAX=0.0
DO 122 J=1,NPTS
YY(J)=Y(J)-YMIN
122 YMAX=AMAX1(YMAX,YY(J))
121 ZERO=-YMIN/YMAX*100.3*1.3
122 LINE(J)=IBLANK
LINE(1)=IDOT
LINE(122)=IDOT
LINE(121)=IEE
IF(I(J).EQ.3) GO TO 129
YY=Y(L)/YMAX*100.3*1.3
YY=FIX(YYYY)
LINE(YY)=PLUS
YYYY=YL(KK)/YMAX*100.0+1.0
YY=FIX(YYYY)
LINE(Y)=IXX
IF(Y.EQ.IYY)LNE(Y)=SAME
KK=KK+1
CONTINUE
WRITE(6,103)LNE
103 FORMAT(2X,122)
CONTINUE
DO 140 J=1,122
LINE(J)=IDOT
WRITE(6,103)LNE
CONTINUE
RETURN