

# Gama-Gama ve Elektron-Gama Yöne Bağlı Korelasyon Deneyleri

## Gamma-Gamma And Electron-Gamma Directional Correlation Experiments

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*The directional correlation measurements is a powerful technique for the study of nuclear structure. The formalism of the method is quite complex, but it can be reduced to simpler forms for the application in the experimental methods.*

*Yöne bağlı korelasyon ölçümleri nükleer yapıyı incelemek için kuvvetli bir metottür. Bu metodun formalize edilmesi oldukça komplekstir, fakat deneysel tatbikatlarda kullanılmak üzere basitleştirilebilirler.*

### INTRODUCTION

In the past decade progress has been made in calculating various properties of nuclei by using specific models. Especially the regions of deformed nuclei are empirically characterised by the occurrence of rotational bands and vibrational states. A unified model of the nucleus including single particle motions, collective rotations and vibrations, pairing plus quadropole excitations have been developed. Calculations have been done on transition probabilities and mixing ratios of transitions in some nuclei in the deformed region which is of particular interest.

All this should have been done by the people who believe that a scientist should endeavour to know the laws, of nature, uncover the hidden treasures of earth, and direct all hitherto unknown forces of mind and matter - all for the betterment of humanity. He should try his level best to explore all avenues of knowledge and power and to harness all that

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exists in earth and the space in the interest of mankind. At every stage of his enquiry his consciousness should save him from making evil and destructive uses of science and scientific methods. He must never conceive himself claiming to be the master of all these objects, boasting to be the conqueror of nature, arrogating to himself the sovereign powers and nourishing the ambition of subverting the world, subduing the human race and establishing his supremacy over all and sundry by means of fair and foul. Such an attitude of revolt and defiance can never be entertained by a person who believes in the peace and the salvation of mankind. Only a cruel scientist can fall prey to such illusions and by submitting to them, expose the entire human race to dangers of total destruction and annihilation. On the other hand, if one has any scientific knowledge he must exert himself for his own good and for the good of humanity. Instead of arrogance there should be humility. Instead of power drunkenness there should be strong realization to serve humanity. His freedom should not be unbridled. Thus science should, in his hands, instead of becoming an instrument of destruction, become an agency for human welfare and moral regeneration..

The directional correlation measurements is a powerful technique for the study of nuclear structure. Forexample the experiments have proved that the pairing plus quadropole interaction as developed by Kumar (1974) has been particularly succesful when applied to nuclei at each end of the deformed region. Directional correlation experiments are being done in the middle of this region and it is expected that the calculations shall be extended to cover the whole deformed region.

If the spins of the nuclei in a radioactive sample are not pointing completely in random directions, then one expects that probabily of detecting a gamma - ray at an angle  $\theta$  with respect to an axis of quantization will not be random. When this is the case the nucleus is said to be oriented. There are two types of orientation :

(1) A state is said to be aligned if the populations of different magnetic substates  $|M_i|$  are different. (If  $J$  is the total angular momentum  $-J \leq M_i \leq J$ ). Thus in a cascade of two gamma rays one would expect the intermediate state to be aligned if  $J_{m_1} \geq 1$ .

(2) A state is said to be polarized if the populations of states with quantum numbers and - are different. Unequal populations of different magnetic states may be obtained when a sample of nuclei is subjected to a magnetic field of strength ( $H$ ) at low temperatures ( $T$ ), such that  $kT \approx \mu H$ . For  $\mu = 1nm$ ,  $H/T = 2.8 \times 10^7$  gauss/°K and the-

refore one needs a large magnetic field and a low temperature to produce nuclear orientation.

The gamma - rays carry a unit of angular momentum which define their multipolarities. A transition may not always have a pure multipolarity, sometimes the multipoles are mixed. If the spins and the multipole mixing ratio of one of the members of a cascade of gamma - rays is known then the other one can be measured, and thus may lead to further information on nuclear structure.

In making a transition from one excited state to another the nucleus can transfer energy and angular momentum to one of the shell electrons in the bound state. This internal conversion process occurs through the interaction of the nuclear currents and charges with the electron via the electromagnetic field. Thus instead of a gamma - ray of multipolarity  $L$ , an electron is converted. The internal conversion electrons may be detected in coincidence with the gamma - rays at different angles, and electron - gamma correlation function can be determined. It will be shown later that this function is not the same as the gamma - gamma directional correlation function and it has got special importance. Even in case of gamma - gamma directional correlations, the internal conversion may have an important role; hence one has to consider and calculate their effect.

The first experimental studies were done by using Geiger counters. Later NaI - NaI detector systems were used, in late Nineteen Sixties NaI - Ge (Li) and Ge (Li) - Ge (Li) detector systems were used. Now the intrinsic germanium detectors are also in use, thus one can set a high resolution, good Ge (Li) - Ge (Int) combination to have precise gamma - gamma directional correlation experiments.

In the following sections a brief summary of the method of calculations and the experimental techniques will be discussed.

### **THEORETICAL CONSIDERATIONS :**

In a cascade of two gamma - rays the probability that the second gamma - ray will be emitted at an angle  $\theta$  with respect to the first one is given by the angular correlation function. This function is defined as the trace of the density matrix of the final state times the efficiency matrix describing the counting system, i.e.

$$W(\theta) = T_r[\rho \in ]$$

The rules of angular momentum algebra as applied by Fraunfelder and Steffen (1966) give :

$$\begin{aligned} W(\theta) = & (-)^{2J_{int} - J_i - J_f} \sum_k \sum_{L_1 L_1'} \sum_{L_2 L_2'} \sum_{\nu_1 \nu_2} (-)^{k - L_1' - L_1} \times \\ & \times \left\{ \begin{matrix} J_{int} & J_{int} & k \\ L_1 & L_1' & J_i \end{matrix} \right\} \times \left\{ \begin{matrix} J_{int} & J_{int} & k \\ L_2 & L_2' & J_f \end{matrix} \right\} \\ & \times \langle J_i \parallel L_1 \pi_1 \parallel J_{int} \rangle \langle J_i \parallel L_1' \pi_1' \parallel J_{int} \rangle^* \times \\ & \times \langle J_f \parallel L_2 \pi_2 \parallel J_{int} \rangle \langle J_f \parallel L_2' \pi_2' \parallel J_{int} \rangle^* \times \\ & \times C_{k\nu_1}(L_1 L_1') C_{k\nu_2}(L_2 L_2') D_{\nu_2 \nu_1}^k(-\theta) \end{aligned}$$

For direction correlations  $\nu_i = 0$ , the detectors are insensitive to polarisation and the matrix elements  $D_{\nu\nu}^k$  are just the Legendre polynomials and the correlation function becomes :

$$W(\theta) = \sum_{k(\text{even})} a_k P_k(\cos\theta)$$

where  $k$  is restricted by

$$0 \leq k \leq \text{Min}(2J_{int}, 2L_1, 2L_2, 2L_1', 2L_2')$$

for most cases  $k = 4$  and the normalised directional correlation function is

$$W(\theta) = 1 + a_2 P_2(\cos\theta) + a_4 P_4(\cos\theta)$$

where

$$a_k = B_k(\gamma_1) A_k(\gamma_2)$$

and

$$B_k(\gamma_1) = [F_k(L_1 L_1' J_i J_{int}) - 2\delta_1 F_k(L_1 L_1' J_i J_{int}) + \delta_1^2 F_k(L_1' L_1' J_i J_{int})] (1 + \delta_1^2)^{-1}$$

$$A_k(\gamma_2) = [F_k(L_2 L_2' J_f J_{int}) + 2\delta_2 F_k(L_2 L_2' J_f J_{int}) + \delta_2^2 F_k(L_2 L_2' J_f J_{int})] (1 + \delta_2^2)^{-1}$$

Here  $\delta$  is the mixing ratio of the transition involved and it is defined as the intensity ratio of the multipolarity  $L'$  to the multipolarity  $L$ , or

$$\delta_1 = \langle J_{int} \parallel \pi' L_1' \parallel J_i \rangle / \langle J_{int} \parallel \pi L_1 \parallel J_i \rangle$$

$$\delta_2 = \langle J_{int} \parallel \pi' L_2' \parallel J_f \rangle / \langle J_{int} \parallel \pi L_2 \parallel J_f \rangle$$

where,  $\Pi$  denotes the electric or magnetic multipoles. The sign of  $\delta$  is consistent with the convention of Krane and Steffen (1970). The  $F$  coefficients are tabulated by Fraunfelder and Steffen (1966). Obviously for pure transitions  $A_k$  and  $B_k$  reduce to the  $F$  coefficients, i.e.

$$B_k = F(L_1, L_1, J_1, J_{int}) \quad \text{and} \quad A_k = F(L_2, L_2, J_f, J_{int})$$

If the cascade involved has more than one intermediate level, the unobserved transitions are given by the deorientation parameters  $U_k$  and

$$W(\theta) = 1 + U_2 a_2 P_2(\cos \theta) + U_4 a_4 P_4(\cos \theta)$$

where

$$U_k = (-)^{L+J_{int}^{(1)}+J_{int}^{(2)}} [(2J_{int}^{(1)}+1)(2J_{int}^{(2)}+1)]^{1/2} \times \\ \times \begin{Bmatrix} J_{int}^{(1)} & J_{int}^{(1)} & L \\ J_{int}^{(2)} & J_{int}^{(2)} & k \end{Bmatrix}$$

if the first intermediate level  $J_{int}^{(1)}$  or the second intermediate level  $J_{int}^{(2)}$  include spin 1/2 then  $U_k = 0$ .

If the unobserved transition is not pure then

$$U_k = \frac{(1+\beta_T) U_k(L) + \delta^2 (1+\alpha_T) U_k(L+1)}{1+\beta_T + (1+\alpha_T) \delta^2}$$

here

$$\beta_T = \alpha_k(L) + \beta_{L_1}(L) + \dots$$

$$\alpha_T = \alpha_k(L+1) + \beta_{L_1}(L+1) + \dots$$

Are the total conversion coefficients. If the conversion coefficients are negligible then :

$$U_k = [U_k(L) + \delta^2 U_k(L+1)] / (1 + \delta^2)$$

If two or more intermediate transitions exist in cascade then the total deorientation parameter is given by the product of the  $U$ -coefficients. If there are two or more intermediate transitions in parallel then one has to take the weighted average of the  $U$ -coefficients using the intensities of each transition.

If the second radiation ( $\gamma_2$ ) is replaced by the  $K$ -shell internal conversion electron line then

$$A_k = b_k^K(\pi L_2) F_k(L_2, L_2) + 2\delta' b_k^K(\pi L_2/\pi' L_2') F_k(L_2, L_2') + \delta'^2 b_k^K(\pi' L') F(L' L') \times \\ \times (1 + \delta'^2)^{-1}$$

Where

$$\delta' = [\alpha_K (\pi' L') / \alpha_K (\pi L)]^{1/2} \delta$$

The particle parameters  $b_k^K$  are tabulated by Hager and Seltzer (1968). There is a useful recurrence relation between  $b_2^K$  and  $b_4^K$  such that

$$b_4^K = 1 + \frac{10}{3} \frac{L(L+1)-3}{L(L+1)-2} (b_2^K + 2)$$

which holds for both electric and magnetic multipolarities. For pure  $E2$  transitions

$$b_4^K = 3.5 - 2.5 b_2^K$$

If there are extra nuclear fields acting on the magnetic moment of the intermediate state ( $J_{int}$ ), then an attenuation coefficient  $G_k$  (Int) will be introduced such that

$$a_k = G_k (\text{Int}) B_k (\gamma_1) A_k (\gamma_2)$$

Here  $G_k$  (Int) depends on the strength of the interaction and the half-life of the intermediate state. Large attenuation effects may be expected when solid sources are used (Steffen and Fraunfelder, 1965) and this may be reduced by using liquid sources.

In the theoretical considerations described above the source and the detectors are assumed to have zero dimensions. i.e. point source and point detectors. Therefore a geometrical correction factor  $Q_k$  must be defined to account for the finite size of the source and the detector. For gamma-ray detectors these correction factors have been tabulated: Yates (1966) calculated the  $Q$  factors for NaI (Tl) detectors, Camp and Van Lehn (1969) for Germanium detectors. Also a method of direct measurement was suggested by Win and Sarantites (1968) for the Ge (Li) detectors. The method involves making spherical diaphragms from a suitable material for every energy. The ratio of counts with and without the diaphragm is then proportional to the correction factor  $Q$ . Experimental verification show that this method seems reasonably successful for large Ge (Li) detectors, but not so for smaller ones, because as the detector gets smaller the finite size of the source becomes more important and the diaphragms may not be approximated to have a spherical surface. The  $Q$  factors for magnetic lens spectrometers are measured by using special bufiles designed for them. In short the ratio of the average counts by using  $P_2$  bufile to the average counts by using the  $P_0$  bufile gives the  $Q_2$  and a similar measurement is done for  $Q_1$  (Kleinheinz et al., 1965).

## THE EXPERIMENTAL TECHNIQUE

Experimental study of gamma-rays and the internal conversion electrons require efficient detectors and electronic instruments. In most cases one has to be able to detect gamma-rays of few keV separation and select events within few nanoseconds. Data has to be stored efficiently and time must not be spent on preliminary experiments as the half life of the radioactive source of interest may be very short. The source must be prepared properly, i.e. it must be pure; it must have certain dimensions; in the case of a liquid source one must find a suitable solution so that it will not introduce any time dependent perturbation; and in the case of a solid source one needs a clean surface and a thin material in order to avoid electron scattering within the source itself and a source made on a material which has a high  $Z$  may introduce attenuation of low energy gamma-rays depending on the detector position.

In the following sections the experimental logic of detection, instrumentation, and the event selection is discussed, and the general apparatus is explained.

### (1) DETECTION

The low energy gamma rays of interest may range from 30 keV to 150 keV, then another group of energies may be between 100 to 300 keV or 100 to 2000 keV. Although a completely different combination of energies may occur, it would be useful to have Ge (Li) or Ge (Intrinsic) detectors to detect efficiently in these regions. Good Ge detectors have a resolution of about 2 keV at 1.33 MeV (30 cm<sup>3</sup>, 15 - 20 % efficient) and about 450 eV at 122 keV (0.5 cm<sup>3</sup>, 1 cm<sup>2</sup>).

A 7.6 × 7.6 cm NaI (Tl) detector is commonly used when there are well separated lines which can be resolved within 8 %. It is also necessary to employ such a detector whenever the gamma-rays of interest are not intense enough and the half life of the source is short so that the Germanium detectors may not be used for long times.

A very high resolution (~.015 %) iron free double focusing beta-ray spectrometer is built recently by Christmas and Cross (1973). However the classical design of the electron spectrometer is described by Kleinheinz et al. (1965) and Falk et al (1967). This design is particularly useful to avoid the Compton scattered gamma-rays and it has

a maximum transmission of 2 % of  $4\pi$ . At this transmission the resolution is about 4 % and it improves down to 1.8 % when the transmission is 0.5 % of  $4\pi$ . The resolution depends on the centring of the source very much if the source is not well centered it may reduce the resolution more than two times.

When this spectrometer is used it is important to remember that the noise due to the photomultiplier must not be amplified above the discriminator level. This can be observed comparing the spectrum which is gated by the discriminator and the spectrum obtained directly from the amplifier. This is especially important when low energy electrons are being detected, and the pulses obtained from the photomultiplier are just above the noise. In such cases a cooling system is employed and it cools the photomultiplier down to  $-5^{\circ}\text{C}$ . This is especially advantageous when the electron energy is of the order of 60 to 150 keV.

The spectrometer should have a power supply which may be automatically controlled to scan the electron spectrum. Once the electron spectrum is determined, one can decide the necessary current to select a certain internal conversion electron line.

One would use the spectrometer when it is necessary to measure the particle parameter of a certain transition. On the other hand if the conversion coefficient of a transition is large and its particle parameter is known then it may be convenient to set a gate on internal conversion electrons by using the spectrometer. This is because as discussed previously the expression for the gamma-gamma correlations is not the same as the one for the electron-gamma correlations, and therefore the shapes of the two types of correlations are different. Whenever this spectrometer is used, if the parent nucleus decays through  $\beta^-$  emission it may be necessary to determine the background contribution experimentally, however if the parent nucleus decays by  $\beta^+$  emission then a bufile can be used to stop the  $\beta^+$  particles.

## (2) AMPLIFICATION AND TIMING

The pulses which carry timing information may not be good enough for energy resolution and the pulses which carry energy information may not be good enough for time resolution; therefore these two aspects of detector pulse output are considered separately when the pre-amplifiers and the amplifiers are designed. In some detectors the pre-amplifiers are designed to give a fast output for timing purposes and



a slow output for energy resolution. In others the output from the pre-amplifier is connected to an amplifier which then gives two output pulses, one for energy and the other for timing. In the spectrometer described a plastic scintillator is used this gives a fast output for timing purposes, while the energy is determined by using the magnetic field.

The pulses used for timing must be amplified properly so that the «jitter» and the «walk» on the pulses may be minimum.

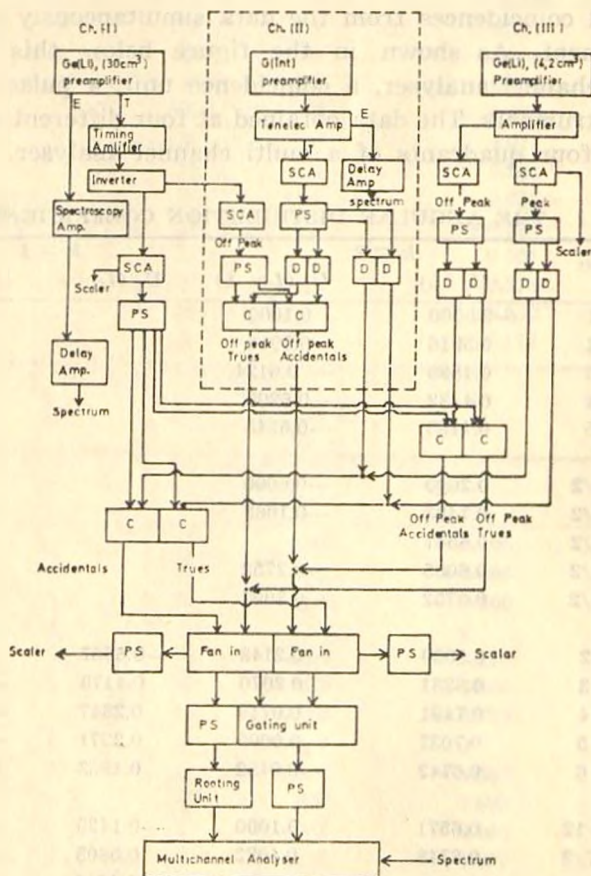
«Jitter» is the noise on the pulses, and it causes the pulses to reach the discriminator sooner or later, and thus causes a fluctuation in time. Jitter is indirectly proportional to the slope of the pulses; hence if a pulse is high enough and its rise time is short jitter is small at the steep edges. Thus it can be minimised by using higher amplification and shorter time constants.

Two or more pulses generated by the events which occur, at the same time may cross the discriminator level at different times; this is called «walk». It can be eliminated by adjusting the amplification and the amplifier time constants, and using single channel analysers which are designed to operate at the zero crossing point of the fast bipolar output of an amplifier. These single channel analysers have walk adjustment which can be set so that all the pulses cross the same point on the discriminator level.

### (3) EVENT SELECTION AND THE GENERAL SET UP

The single channel analysers give logic outputs operating on the zero crossing. These logic pulses (0.6 V, 20 nsec, negative) are then fed into a pulse shaper which gives output pulses of adjusted width. The outputs of all detectors except the spectrometer can be treated in this way. The shaped pulses then go to overlap coincidence unit which has its resolving time set by the sum of the incoming pulse widths. In another method, the logic pulses from single channel analysers can be fed directly to the coincidence unit which has its resolving time set internally. In cases where the spectrometer is used, the spectrometer output should be amplified and then fed to a pulse shaper discriminator and the outputs of this are connected to the delay units which gives pulses directly to the coincidence units.

As far as the general set up is concerned, one detector should be kept stationary and the other detector moves around the source at regular time intervals, short enough to avoid the fluctuations due to electronic drifts, and stop at four different angles with respect to the stationary detector. Depending on the energy, intensity and the conversion coefficient of the selected transition a Germanium detector, a NaI (TI) crystal or the spectrometer may be used as the stationary detector and



The set up for automatic off the peak correlation subtraction. Either channel (II) or channel (III) should be used together with Ch. (I)

- ECA — single channel analyser
- C — fast coincidence unit
- D — delay
- PS — Pulse Shaper

a Germanium detector or a NaI (Tl) crystal may be used to take the spectrum at four angles in coincidence with the stationary detector.

When a peak of certain energy is gated there is always a background contribution which is due to the Compton scattering accumulated under that peak. In a simple detecting system this off the peak correlation is run separately and it has to be corrected for time, whenever the half life of the source is short. To do this correction without any calculations, one should subtract the off the peak correlation and the accidental coincidences from the data simultaneously in the course of an experiment. As shown in the figure below this requires an extra single channel analyser, a coincidence unit, a pulse adder and a few other instruments. The data obtained at four different angles should be stored in four quadrants of a multi channel analyser.

Table 1. THE ANGULAR DISTRIBUTION COEFFICIENTS.

$J_f$	$J_{int}$	$k = 2$		$k = 4$	
		$U_k(L)$	$U_k(L+1)$	$U_k(L)$	$U_k(L+1)$
1	1	-0.5000	0.1000		
	2	0.5916	-0.5916		
	3	0.4899	-0.6124		
	4	0.4432	-0.6205		
	5	0.4163	-0.6245		
3/2	3/2	0.2000	-0.6000		
	5/2	0.7483	-0.1069		
	7/2	0.6547			
	9/2	0.6055	-0.2752		
	11/2	0.5752	-0.3097		
2	2	0.5000	-0.2143	-0.6667	0.2857
	3	0.8281	0.2070	0.4179	-0.6268
	4	0.7491	0.0749	0.2847	-0.5694
	5	0.7037	0.0000	0.2271	-0.5300
	6	0.6742	-0.0482	0.1953	-0.5023
5/2	5/2	0.6571	0.1000	-0.1429	-0.5000
	7/2	0.8748	0.4082	0.5803	-0.4513
	9/2	0.8092	0.2795	0.4349	-0.5140
	11/2	0.7687	0.2010	0.3624	-0.5296
	13/2	0.7412	0.1482	0.3192	-0.5320
3	3	0.7500	0.3167	0.1667	-0.5000
	4	0.9047	0.5428	0.6814	-0.2271
	5	0.8498	0.4249	0.5436	-0.3624
	6	0.8142	0.3489	0.4675	-0.4230
	7	0.7891	0.2959	0.4195	-0.4545

Table 2. THE F - COEFFICIENTS ( $J = J_1$  or )

$J_{int} = 1$			
$L$	$L'$	$J$	$F_2$
1	1	0	0.707
0	1	1	0
0	2	1	-2.236
1	1	1	-0.354
1	2	1	-1.061
2	2	1	-0.354
1	1	2	0.474
1	2	2	0.071
2	2	2	0.354
2	3	2	-0.632
3	3	2	-0.421
2	2	3	-0.101
2	3	3	0.378
3	3	3	0.530
3	3	4	-0.177

 $J_{int} = 3/2$ 

1	1	1/2	0.500
1	2	1/2	-0.866
2	2	1/2	-0.500
0	1	3/2	0
0	2	3/2	-2.236
1	1	3/2	-0.400
1	2	3/2	-0.775
2	2	3/2	0
2	3	3/2	-0.632
3	3	3/2	0.600
1	1	5/2	0.100
1	2	5/2	0.592
2	2	5/2	0.357
2	3	5/2	-0.338
3	3	5/2	0.150
2	2	7/2	-0.143
3	3	7/2	-0.463
3	3	7/2	0.500
3	3	7/2	0.500
3	3	9/2	-0.250

$J_{int} = 2$ 

2	2	0	-0.598	-1.069
1	1	1	0.418	0
1	2	1	-0.935	0
2	2	1	-0.299	0.713
2	3	1	-0.535	0.996
3	3	1	-0.717	0.089
0	1	2	0	0
0	2	2	-2.236	0
1	1	2	-0.418	0
1	2	2	-0.612	0
2	2	2	0.128	-0.305
2	3	2	-0.571	-0.798
3	3	2	-0.179	-0.134
1	1	3	0.120	0
1	2	3	0.655	0
2	2	3	0.341	0.076
2	3	3	-0.175	0.326
3	3	3	0.329	0.089
2	2	4	-0.171	-0.008
2	3	4	0.505	-0.063
3	3	4	0.448	-0.030
3	3	5	-0.299	0.004

 $J_{int} = 5/2$ 

2	2	1/2	-0.535	-0.617
2	3	1/2	-0.378	1.091
3	3	1/2	-0.802	0.154
1	1	3/2	0.374	0
1	2	3/2	-0.949	0
2	2	3/2	-0.191	0.705
2	3	3/2	-0.587	0.326
3	3	3/2	-0.441	-0.077
0	1	5/2	0	0
0	2	5/2	-2.236	0
1	1	5/2	-0.507	0
1	2	5/2	0.191	-0.397
2	2	5/2	-0.428	0
2	3	5/2	-0.498	-0.798
3	3	5/2	0.027	-0.077
1	1	7/2	0.134	0
1	2	7/2	0.694	0
2	2	7/2	0.325	0.118
2	3	7/2	-0.071	0.447
3	3	7/2	0.401	0.103
2	2	9/2	-0.191	-0.015
2	3	9/2	0.530	-0.102
3	3	9/2	0.401	-0.044
3	3	11/2	-0.334	0.007

$J_{int}=3$ 

3	3	0	-0.866	0.213
2	2	1	-0.495	-0.447
2	3	1	-0.463	1.045
3	3	1	-0.650	0.036
1	1	2	0.346	0
1	2	2	-0.949	0
2	2	2	-0.121	0.670
2	3	2	-0.592	0
3	3	2	-0.274	-0.107
0	1	3	0	0
0	2	3	-2.236	0
1	1	3	-0.433	0
1	2	3	-0.433	0
2	2	3	0.227	-0.6447
2	3	3	-0.436	-0.739
3	3	3	0.144	0
1	1	4	0.722	0
1	2	4	0.144	-0.036
2	2	4	0.309	0.149
2	3	4	0	0.520
3	3	4	0.433	0.104
2	2	5	-0.206	-0.020
2	3	5	0.546	-0.134
3	3	5	0.361	-0.055
3	3	6	-0.361	0.010

 $J_{int}=7/2$ 

3	3	1/2	-0.818	0.171
2	2	3/2	0.468	-0.358
2	3	3/2	-0.505	0.967
3	3	3/2	-0.546	-0.019
1	1	5/2	0.327	0
1	2	5/2	-0.945	0
2	2	5/2	-0.078	0.6377
2	3	5/2	-0.583	-0.186
3	3	5/2	-0.164	-0.108
0	1	7/2	-2.236	0
0	2	7/2	-0.436	0
1	1	7/2	0	0
1	2	7/2	-0.378	0
2	3	7/2	0.249	0.478
			-0.387	-0.673
3	3	7/2	0.218	-0.007
1	1	9/2	0.153	0
1	2	9/2	0.742	0
2	2	9/2	0.296	0.174
2	3	9/2	0.052	0.567
3	3	9/2	0.447	0.102
2	2	11/2	-0.218	-0.025
2	3	11/2	0.556	-0.161
3	3	13/2	0.327	-0.063
			0.382	0.012

$$J_{int} = 4$$

3	3	1	-0.783	0.145
2	2	2	-0.448	-0.304
2	3	2	-0.530	0.900
3	3	2	-0.470	-0.048
1	1	3	0.313	0
1	2	3	-0.940	0
2	2	3	-0.045	0.609
2	3	3	-0.571	-0.304
3	3	3	-0.085	-0.101
0	1	4	0	0
0	2	4	-2,236	0
1	1	4	-0.439	0
1	2	4	-0.335	0
2	2	4	0.265	-0.498
2	3	4	-0.347	-0.614
3	3	4	0.269	0.013
1	1	5	0.160	0
1	2	5	0.757	0
2	2	5	0.285	0.194
2	3	5	0.092	0.601
3	3	5	0.453	0.098
2	2	6	-0.228	-0.030
2	3	6	0.564	-0.184
3	3	6	0.299	-0.069
3	3	7	-0.399	0.014

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