JAN 2 2 1991

STUDIES OF THE SPIN-ISOSPIN RESPONSE OF
THE NUCLEAR CONTINUUM USING INTERMEDIATE
ENERGY HADRONS

PROGRESS REPORT

Dr. F. Todd Baker
Univerity of Georgia Research Foundation
Athens, GA 30602

December 1990

PREPARED FOR THE
U.S. DEPARTMENT OF ENERGY
UNDER GRANT DE-FG09-87ER40354-3

MASTER

DM

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

TECHNICAL PROGRESS REPORT (1989-90)

AND PLANS FOR 1991

Studies of the Spin-Isospin Response of the Nuclear

Continuum Using Intermediate-Energy Hadrons

F. Todd Baker, Principal Investigator

(DE-FG09-87ER40354)

I. EXPERIMENTAL ACTIVITY

During the calendar years 1989 and 1990 the following experiments were performed:

- i) $^{12}\text{C}(\vec{d}, \vec{d}')$, $E_d=400$ MeV, at SATURNE in October, November, 1989,
- ii) $^{40}\text{Ca}(\vec{p}, \vec{p}')$, $E_p=500$ MeV, at LAMPF in May, June, 1990,
- iii) Development of the Medium-Resolution Spectrometer (MRS) and focal-plane polarimeter at LAMPF, July-October, 1990,
- iv) $^{40}\text{Ca}(\vec{d}, \vec{d}')$, $E_d=400$ MeV, at SATURNE in September, October 1990.

The purpose of the $^{12}\text{C}(\vec{d}, \vec{d}')$ experiment was to test whether a good signature of $\Delta S=1$, $\Delta T=0$ transitions could be found. This would be important because there is very little known about isoscalar $S=1$ strength in the continuum. Such a signature was found and the results have been published¹ and are briefly discussed in Section IV. below.

The purpose of the $^{40}\text{Ca}(\vec{p}, \vec{p}')$ experiment was to measure a complete set of spin observables in the continuum to separate the nuclear response into its longitudinal and transverse parts to see if either carries the bulk of the previously observed^{2,3} enhancement of the $S=1$ strength in the continuum. The data reduction for this experiment has been recently completed and will be discussed below in Section IV.

The MRS development was done over a period of approximately five weeks in the summer and early fall of 1990. Although the official LAMPF schedule showed experiment 1131 as running, since the focal plane polarimeter had been previously unused and since only partial understanding of the optics of the MRS had been previously attained, very little if any new physics was achieved. Nevertheless, substantial progress in understanding

the MRS was made which should permit more productive use of the instrument in the future.

The $^{40}\text{Ca}(\vec{d},\vec{d}')$ experiment was performed to determine the isoscalar $\Delta S=1$ strength in the continuum and to compare these results with our previous results for (mainly) isovector strength deduced from the $(\vec{p},\vec{p}')$ experiment. These data have not yet been reduced.

During the period covered in this report I also spent some time at laboratories doing data reduction and analysis. I spent the month of April 1989 at KEK, Tskuba, Japan doing analysis of data acquired for the (p,n) quasifree Δ production experiment. I spent five weeks at LAMPF in the summer of 1989 doing replay of data from the 319 MeV $^{48}\text{Ca}(\vec{p},\vec{p}')$ experiment.

II. PENDING AND APPROVED EXPERIMENTS

Several experiments are pending:

"Extended Angular Range of S_{nn} Measurements in ^{40}Ca " for which I am the spokesman, was approved with a high (A^-) priority in January 1988. It has not yet been scheduled mainly because the beam energy, 319 MeV, is infrequently scheduled. The proposal was updated at the August PAC meeting, retained its A^- priority, and had the approved running time increased by a factor of $(80/60)^2$ to compensate for the new polarized ion source (OPPIS) which has lower polarization than the source operating when the proposal was first written. I am hopeful that this experiment, which is an important next step in my program in that it should allow separation of higher multipoles, will be scheduled during 1991.

As noted above, Experiment 1131, "Measurements of Polarization Transfer for 800 MeV Inclusive Proton Scattering at the MRS", received substantial running time in 1990 but this time served mainly as MRS development. We anticipate that a considerable amount of additional running time will be awarded in this case. The purpose of this experiment is to measure, in the quasielastic and delta regions, complete spin observables

at 800 MeV for the $^{40}\text{Ca}(\vec{p},\vec{p}')$ reaction.

Another experiment for MRS at LAMPF is Experiment 1145, "Measurements of Complete Spin Observables in Quasifree Region". This experiment, to be done at 500 MeV, has an A priority and has a high probability of being scheduled in 1991.

Another experiment for which I am spokesman is Experiment 1142, "Isovector/Isoscalar Decomposition for the $\Delta S=1$ Continuum in ^{40}Ca ". Here we have proposed to study the $^{40}\text{Ca}(\vec{p},\vec{n})$ reaction at 319 MeV at NTOF at LAMPF. The spin-flip cross section should proceed exclusively via $\Delta T=1$, $\Delta S=1$ and comparing the results with our $^{40}\text{Ca}(\vec{p},\vec{p}')$ results which should include both $\Delta T=0$ and $\Delta T=1$ transitions we should be able to get information on isoscalar $\Delta S=1$ strength which would serve as an independent measurement with which to compare our $^{40}\text{Ca}(\vec{d},\vec{d}')$ results at SATURNE. However, this experiment has two things going against its early scheduling—it has only a B⁺ priority and the neutron polarimeter has not yet been calibrated at 319 MeV. It is unlikely to be scheduled before 1992.

I am a participant for an experiment which was approved by the LAMPF PAC in August 1990, "Precision Measurement of D_{nn} for $^{13}\text{C}(\vec{p},\vec{p})$ at 500 MeV". The idea here is to look for signatures of relativistic effects in the very small spin-flip probabilities of elastic scattering from this odd-A nucleus.

I am also a participant in an update to be submitted to the LAMPF PAC in January. This proposal is to make precision ($\sim 1\%$) determinations of elastic scattering cross sections for angles in to 1° . This experiment has been previously approved for development which is now complete and there is every reason why it should be expected to run in summer of 1991.

It is quite likely that additional experiments will be proposed at SATURNE because of the auspicious beginning of the $(\vec{d},\vec{d}')$ experiments which have been done. The data analysis of the $^{40}\text{Ca}(\vec{d},\vec{d}')$ needs to be completed before we can intelligently propose the next step in this program. I am hoping to extend the schematic model which I have

developed for analysis of our $(\vec{p}, \vec{p}')$ data to be useful for the $(\vec{d}, \vec{d}')$ data.

III. CONFERENCES ATTENDED

I attended the 7th International Conference on Polarization Phenomena in Nuclear Physics held in Paris in 1990. I was a coauthor of four contributed papers and presented an invited contribution entitled "Spin/Isospin/Multipole Response of the Nuclear Continuum Using Hadron Scattering".

IV. MAIN RESULTS TO DATE

In this section I will discuss some of the main results. In the cases where these results have been published I will only briefly discuss them here.

Strength distributions of the spin dipole and spin quadrupole strengths were determined for ^{40}Ca . To do this we developed a schematic model to provide prototype angular distributions for the spin-flip cross section $\sigma_{\text{SF}} = \sigma_{\text{Snn}}$. These results have been published⁴; similar analyses of $^{44}\text{Ca}(\vec{p}, \vec{p}')$ at $E_p = 290$ MeV and $^{48}\text{Ca}(\vec{p}, \vec{p}')$ at $E_p = 318$ MeV have been completed and are being prepared for publication.

The enhanced spin response of the nuclear continuum which we have noted^{2,3} is now, I believe, reasonably well understood. This enhancement, at the angles where we have observed it, is due to two effects. First, where $qR \sim 2.0$ fm, very little cross section from $\Delta S = 0$, $\Delta L \geq 2$ is expected because cross sections peak near $qR \sim \sqrt{l(l+1)}$; indeed, we observe, for a wide range of targets and incident energies, that about 90% of the cross section for $\omega > 30$ MeV is due to $\Delta S = 1$ transitions. For somewhat larger angles, $qR \sim 2.4$ fm where $\Delta L = 2$ should be large, in all cases but one the situation is the same, i. e. the response for $\omega > 30$ MeV is approximately 90% $\Delta S = 1$. This is attributable to the fact that the $\Delta L = 2$, $\Delta S = 0$ strength is nearly exhausted in the low-lying giant quadrupole resonance. The one case where the response is not mainly $\Delta S = 1$ at $qR \sim 2.4$ is $^{12}\text{C}(\vec{p}, \vec{p}')$ at $E_p = 318$ MeV; this is because, as is well known, ^{12}C does not have a well-defined giant quadrupole resonance which exhausts a large fraction of the sum rule. These results were presented in my invited talk at the Paris90 Polarization Conference.

The ($\vec{d}, \vec{d}'$) experiments which have been done at SATURNE have attempted to isolate the $\Delta S=1$, $\Delta T=0$ part of the spectrum; if this can be done the distribution of the isoscalar spin strength can, for the first time, be studied. Deuterons should excite only isoscalar transitions but both $\Delta S=0$ and $\Delta S=1$ (and possibly $\Delta S=2$). To isolate the $\Delta S=1$ part of the spectrum we seek an analogy of S_{nn} for deuterons. It may be shown that the probability for transferring one unit of spin to the nucleus is given by

$$P(1) = (8 - 2A_{yy} - 2P^{yy} - 4K_{yy}^{yy})/18.$$

This would require a tensor polarimeter to measure. Since we have available only a vector polarimeter, POMME, we make the following approximations:

$$P(2) \approx 0$$

$$P^{yy} \approx A_{yy}$$

which lead to

$$P(1) \approx (4 + 2A_{yy} - 6K_y^y)/3.$$

One of the purposes of the ^{12}C experiment was to test these approximations. The known $\Delta S=0$ states in ^{12}C (2^+ , 0^+ , 3^-) are very effectively suppressed in the $\sigma P(1)$ spectrum.

There is no evidence in the spectrum for any known isovector transitions (particularly the 1^+ state at 15.1 MeV). The known $\Delta S=1$, $\Delta T=0$ states (12.71 MeV 1^+ and 18.3 MeV 2^-), on the other hand, are quite apparent in the $\sigma P(1)$ spectrum. Considerable $\Delta S=1$, $\Delta T=0$ strength is also evident in the continuum. These results have also been published¹ and data for ^{40}Ca have been obtained to exploit the method of studying isoscalar spin excitations.

For ^{40}Ca complete spin observables D_{ij} have been measured at 500 and 580 MeV to determine whether the enhanced spin response is preferentially either transverse or longitudinal. These data have now been completely replayed and will constitute the Ph. D. dissertation of Andrew Green (Rutgers University). Interestingly, although the spin-flip probability S_{nn} appears rather insensitive to distortions and fermi-motion corrections, the longitudinal and transverse spin-flip probabilities S_L and S_T are more sensitive

individually. The fermi-motion corrections, done using the optimal frame⁵, have a sizable effect on S_T but not on S_L ; the effects of distortions increase S_L but have a very small effect on S_T ⁶. These effects were discussed in my invited talk at Paris90 and an article describing the results is in preparation.

V. GRADUATE STUDENTS

I currently have one graduate student working with me, Mr. Bruce Storm. He now has acquired quite a bit of experience at LAMPF, having spent the summer of 1989 there and a good portion of the summer of 1990 there. He attended the LAMPF summer school for graduate students during the summer of 1990. He has nearly completed his coursework and hopes to pass his Ph. D. qualifying examinations in September 1991. He will be working, during the current academic year, on a Master's thesis on the $^{12}\text{C}(\vec{p},\vec{p}')$ data acquired at LAMPF.

VI. PUBLICATIONS

REFEREED PAPERS PUBLISHED:

" $^{192}\text{Os}(\vec{p},p')$ Reaction at 135 MeV", F. T. Baker, A. Sethi, V. Penumetcha, G. T. Emery, W. P. Jones, M. A. Grimm, and M. L. Whiten, Nucl. Phys. A501 (1989) 546.

"Spin Dipole and Quadrupole Resonances in ^{40}Ca ", F. T. Baker, L. Bimbot, C. Glashauser, A. Green, K. Jones, W. G. Love, and S. Nanda, Phys. Rev. C40 (1989) 1877.

"The Nuclear Spin Response to Intermediate Energy Protons", F. T. Baker *et al.*, Phys. Lett. 237B (1990) 337.

"Signatures for Isoscalar Spin Transitions Excited in $(\vec{d},\vec{d}')$ Transitions", M. Morlet *et al.*, Phys. Lett. 247B (1990) 228.

" $^{194,198}\text{Pt}(\vec{p},p')$ Reaction and the Interacting Boson Model", A. Sethi, F. T. Baker, G. T. Emery, W. P. Jones, and M. A. Grimm, Nucl. Phys. A518 (1990) 536.

PAPERS ACCEPTED FOR PUBLICATION:

"The Nuclear Spin Response of ^{40}Ca to 800 MeV Protons", L. Bimbot *et al.*, Phys. Rev. C.

PAPERS SUBMITTED FOR PUBLICATION:

"The Nuclear Response in the $^{54}\text{Fe}(\vec{p},\vec{p}')$ Reaction at 290 MeV", O. Häusser *et al.*, Phys. Rev. C.

CONFERENCE PROCEEDINGS:

" $^{40,44,48}\text{Ca}(\vec{p},\vec{p}')$ at $E \approx 300$ MeV", F. T. Baker *et al.*, 7th International Conference on Polarization Phenomena in Nuclear Physics (1990) [contributed paper].

"Longitudinal/Transverse Separation of the Spin Response of ^{40}Ca to 580 MeV Protons", A. Green *et al.*, 7th International Conference on Polarization Phenomena in Nuclear Physics (1990) [contributed paper].

"Signatures for Isoscalar Spin Transitions Excited in $(\vec{d},\vec{d}')$ Reactions", M. Morlet *et al.*, 7th International Conference on Polarization Phenomena in Nuclear Physics (1990) [contributed paper].

"Comparison of the Relative Spin Response of ^{12}C and ^{208}Pb to Intermediate Energy Protons", X. Y. Chen *et al.*, 7th International Conference on Polarization Phenomena in Nuclear Physics (1990) [contributed paper].

"Spin/Isospin/Multipole Response of the Nuclear Continuum Using Hadron Scattering", F. T. Baker, 7th International Conference on Polarization Phenomena in Nuclear Physics (1990) [invited paper].

REFERENCES

- 1 M. Morlet *et al.*, Phys. Lett. 247B (1990) 228.
- 2 C. Glashauser *et al.*, Phys. Rev. Lett. 58 (1987) 2404.
- 3 "The Nuclear Spin Response to Intermediate Energy Protons", F. T. Baker *et al.*, Phys. Lett. 237B (1990) 337.
- 4 "Spin Dipole and Quadrupole Resonances in ^{40}Ca ", F. T. Baker *et al.*, Phys. Rev. C40 (1989) 1877.
- 5 R. D. Smith, Nucleon-Nucleus Scattering to the Continuum, in "Spin Observables of Nuclear Probes", C. Horowitz *et al.*, eds., Plenum Press, New York (1988).
- 6 W. Unkelbach, Private Communication.

Papers removed and cycled separately.

END

DATE FILMED

02 / 07 / 91