MASTER

DOE/ER/10516--10

DE82 006903

"NUCLEON-NUCLEON THEORY AND PHENOMENOLOGY"

A

Progress Report

and

Renewal Proposal

from

Michigan State University

to the

U. S. Department of Energy

Division of Nuclear Physics

6/1/82 - 5/31/83

\$95,120

Peter Signell
Principal Investigator

12/29/81

Sam Austin, Chairman
Department of Physics

HOWARD G. GRIDER
Director Contract and Grant Administration

DISCLAIMER

This book 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.

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.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

PROGRESS REPORT AND RENEWAL PROPOSAL

Peter Signell
Physics Department
Michigan State University
East Lansing, MI 48824

1. SUMMARY

This project has now been under way for a little over two years. We have been working mainly on five inter-related subprojects: (i) derivation of the intermediate range nucleon-nucleon interaction with the new dramatically altered $\pi\pi$ s-wave interaction and using a new method that utilizes much shorter and simpler analytic continuation through the unphysical region that lies between the πN and $\pi\pi$ physical regions of the $NN \rightarrow \pi\pi$ amplitude (with significantly improved accuracy for the nucleon-nucleon interaction); (ii) construction of a short range phenomenological potential that, with the theoretical part mentioned above, gives a precise fit to the nucleon-nucleon data and is parameterized for easy use in nucleon calculations; (iii) phase shift analyses of the world data below 400 MeV, especially the large amount of very precise data below 20 MeV and the new data near 55 MeV that have never been analyzed properly, and determining which phases are given by theory at which energies; (iv) the introduction of our K-matrix formulation of the Optimal Polynomial Expansion in order to accelerate convergence of the partial wave series at LAMPF energies; and (v) setting up of a cooperatively evaluated and verified permanent nucleon-nucleon data bank in the 0-1200 MeV range that can be used by all nucleon-nucleon researchers (or anyone else) via Telenet dial-in and by means of a published compendium. For (i) we are collaborating with LASL and will assess comparisons with other results in cooperation with colleagues representing the PARIS and Stony Brook interactions. For (iii) we are currently collaborating with experimentalists at Wisconsin, Zurich, and LASL. For (iv) we have received assurances from colleagues at VPI and Texas A & M of their intent to try the resulting formalism in their data analyses. For (v) we are working in close cooperation with the Texas A & M and VPI groups, and are getting good help from sundry experimentalists. Good progress has been made in all five subprojects, with results to be published in all five within the upcoming contract period.

As a secondary ("background") project, we are beginning to provide some prototype support services for theoretical and computational physics. These include the construction of principles for the design of modern dial-in information systems for physics, including data banks, electronic messaging and conferencing, software sharing, preprint and "experiments in progress" information, scientific text processing, and computer programming. As a result of working on the NSF/DOE NSAC Nuclear Theory Computational Capabilities Subcommittee, we have begun to set up a prototype software exchange service, making use of the wide range of computer capabilities publicly available on the MERIT

Computer Network. Our present program is a very low-budget prototype operation, designed to test models of software exchange and help the community gain experience. This should be useful whether or not a dedicated theory computer center is eventually set up somewhere.

2. ANALYSIS OF THE LOW-ENERGY NUCLEON-NUCLEON DATA

The nucleon-nucleon p-wave scattering lengths and effective ranges have been practically unknown, and this has prevented analysis of the large amount of very beautiful data below 1 MeV. In recent years Thomann, Benn, and Munch have experimentally mapped out the dramatic Coulomb-nuclear interference dip in the proton-proton angular distribution, a sudden dip in the cross section of two orders of magnitude. This is one of the most spectacular interference dips in nuclear physics. Analyses have shown us that the s-wave parameters at low energies are sensitive to the assumed p-waves.

The p-wave scattering lengths and effective ranges have now been determined by us, in collaboration with Haeberli, Barker and Colby at Wisconsin, from their new ultra - precise polarization measurements at 5 and 10 MeV plus the recent 5- and 10-MeV cross sections by Heglund et al and Imai et al. The new measurements are so accurate that they cause the uncertainties in the p-wave parameters to shrink by almost an order of magnitude. They are now precise enough to allow analyses of the lower energy data in order to determine the s-wave parameters.

A problem associated with the analysis of the new data below 10 MeV is that Perez has found relativistic electromagnetic corrections large enough to make dramatic changes in the fits to existing data in this energy range. Solving the problem of relativistic corrections to the electromagnetic interaction between two protons is not as easy as one might expect. Perez took the non-relativistic limit of the one photon exchange diagram, but keeping terms to order v^2/c^2 . However, there is no reason to expect that Perez's procedure should produce a realistic amplitude for low energies. For example, the Coulomb phase expansion parameter is e^2/k , which does not produce good Born series convergence when k is small. Instead of Perez's procedure, we need a method that solves the multi-photon exchange problem to order v^2/c^2 . The electromagnetic interaction we need, good to order v^2/c^2 , has already been produced and verified. The interaction is derived by starting with the Salpeter equation and making a nonrelativistic reduction, keeping v^2/c^2 terms, without using perturbation theory. The interaction has a large number of terms, but we are now nearing completion of the program to evaluate it. When finished, we will use it in data analyses. The result should provide the definitive answer to the question of relativistic effects in ultra-accurate data at low energies. Since the interaction is effectively a potential energy, we will be able to add it to our parameterized strong interaction potential and make a clean separation between the nuclear and electromagnetic interactions.

The analysis of the large amount of very precise PP data below 1 MeV, and somewhat less precise data in the range 1-10 MeV, depends on obtaining a representation for the 1S_0 phase shift. There has been a long-standing claim by Noyes that removal of the 1π -exchange cut from the 1S_0 partial wave amplitude allows one to represent that amplitude up to 10 MeV by an effective range series with just two terms. Noyes' claim was based on comparison to a few crude data. We have rigorously tested the idea through matching the exact phases produced by our new NN potential which has both 1π and 2π cuts. We have found that although removal of the cut improves the fit of the 2-term series, the resulting effective range differs from the true calculated value for that model by over 2%. This is an order of magnitude larger error than that produced by real data. Thus the two term series is useless, with or without Noyes' correction. Further model studies showed that six terms are necessary to match the experimental accuracy, and that then it makes no difference whether the Noyes correction is included or not. We must now repeat the model studies with the Coulomb interaction included, which complicates introduction of a Noyes-type correction. There are data at more than 6 energies so we should be able to make a precise determination of the effective range parameters.

3. NUCLEON-NUCLEON DATA BANK

The field of low-and medium-energy nucleon-nucleon scattering has had little support for obtaining an evaluated data set. The Berkeley Particle Data Group has not covered the energies represented and the Karlsruhe compilation represents unevaluated data and is out of date. If one examines the data currently being used in phase shift analyses, some of the data have had erroneous corrections applied, some have been misidentified, others have been shown to be incorrect by later experiments, and some of the data remain unpublished after being used for years in published analyses. Finally, attempts at "cleaning up" the data tapes used by analysis groups always seem to have to start all over again because information used to make the "cleaning" decisions has been lost or become garbled.

Our solution is to construct a permanent data bank, completely documented, that the various NN groups can easily access electronically. The three analysis groups (VPI, Texas A & M, and MSU), have agreed to cooperate in producing such a data bank. They have assigned us (MSU) the task of data management design and administration. We have had three intensive working sessions with representatives of the Texas A & M group and two with the VPI group. We have immersed ourselves in the field of electronic data management. We read research findings, talked with innumerable data managers in industry and government, visited presumed "state of the art" data management sites, and compared benchmark storage and retrieval costs and results on a variety of systems. We learned to be exceedingly hard nosed, demanding to see each system's experts actually carry out operations typical of those needed for managing and using physics data banks.

During our investigation, we developed a list of principles for the design of physics data management systems. These principles summarize the experience gained in developing on-line data banks in other disciplines. The principles will be published, along with our own implementation of them for the nucleon-nucleon data. This design can be easily adapted for other physics data banks. The design of our bank's first implementation phase is now complete: the on-line NN data bank is emerging. Currently, it can only be accessed by issuing commands. The second phase will consist of verification and evaluation with the other groups, plus a dunning of certain experimentalists to publish their data in a refereed journal or in our data compendium. The third phase will implement both menus and relational calculus for interrogating the data bank.

The three NN analysis groups (MSU, Texas A & M, and VPI) have agreed on a division of labor for bringing up the data bank. The initial entry of most of the data is from VPI and from experimental groups. Texas A & M is verifying all of the data above 400 MeV, MSU all of the data below 400 MeV. Each of these groups is producing a publications file for their respective domains and will supply copies to the other. MSU has been designated Data Bank Administrator for the entire set. We at MSU have verified and documented 4500 data entries, complete with bibliographic information, warnings, and comments. We are now working on the last 2000 lines. By the first of April the data bank will be loaded with enough data to automatically print a preliminary copy in book form and send it out for public comment. This should be finished by the middle of May and evaluation discussions will ensue between the groups. We hope to have all disagreements between the groups resolved by the end of summer '82. The data will then be again automatically printed in book form on MSU's laser printer. The type styles and sizes available on this printer will enable us to print the data bank in a format similar to that used in the Particle Data Group compilations. The printing of our compilation will occur entirely automatically, directly from the data bank. This photographic quality compendium will also include analyses based upon the evaluated data. We plan to issue yearly updates but we will rely upon the automatic dial-in service to keep users up to date with respect to both data and analyses.

There is a growing problem of unpublished data sets, some of which were communicated to the data analysis groups over four years ago. Most of the problem seems to arise because of the availability of Physical Review Letters as a publication medium. Good data are announced there and displayed in figures. However, the numerical values of large data sets, along with discussions of experimental method and analysis of errors, are not suitable for the Letters. In a growing number of cases, this documentation never takes place, even in preprint form, due to pressures of new experiments and collaborations plus the fact that publication credit has already been obtained via the Letter.

The lack of real publication has created a dilemma for us data analysts: should we publish analyses based in good measure on unpublished data? Or should we reject such data, thereby losing the advantage of major data sets that were measured at considerable cost and human effort?

After considerable debate among the groups, we have come to this conclusion regarding unpublished data: if pressure from our analysis groups does not produce the publication, then we will ask permission to publish the data in our compilation. We will secure our own referees from among our experimental colleagues. In most cases there is a Ph.D. thesis that contains all documentation needed by the reviewer, and that material is readily available from University Microfilms. The referees would be rewarded by, for example, being listed as members of the compilation's Board of Advisors. We have already tried this proposal on a delinquent experimentalist and the effect was electric: he immediately started writing the long-awaited paper for regular publication.

4. A NEW NN POTENTIAL FOR NUCLEAR PHYSICS

There has been a recent dramatic change in the experimental values for the $\pi\pi$ s-wave phase shift at low energies, which means that the intermediate range NN potential derived from it will also change. The Paris potential and nuclear physics calculations that used the old values may thereby be obsolete. The new $\pi\pi$ phases are lower than the old ones by a factor of two and they now agree with theoretical expectations from both current algebra and from simple extrapolation of the πN amplitudes. The Paris group used $\bar{N}N \rightarrow \pi\pi$ amplitudes from another group, of which Pietarenan was the mainstay. Pietarenan has now gone off into other areas of physics so we may be the only group left that can fairly easily put in the new $\pi\pi$ phases, get new $\bar{N}N \rightarrow \pi\pi$ amplitudes, and calculate the new intermediate range NN potential. We will then readjust the short range NN potential parameters to match the NN data from the data bank. The resulting NN potential will be the "state of the art" potential for "realistic" nuclear calculations.

5. PROPOSED PROGRAM FOR A PROTOTYPE SOFTWARE EXCHANGE

1. Make a survey of NSF and DOE grantees to determine; (i) software desired via exchange; and (ii) software each group is willing to share.
2. Collect programs with priority determined by demand and availability. Put portable ones in ANSI FORTRAN if necessary. Document the programs.
3. Select a host computer system that has: on-line "round the clock" access via X.25 Telenet or Tymnet connections at 300 and 1200 baud, both CDC and IBM mainframes, modest charges, and an automatic output mailing capability.
4. Put each portable program into a card-image file that can be copied by users. Implement each non-portable program on the

appropriate mainframe.

5. Use electronic messaging and conferencing to provide consulting assistance, to disseminate users' experiences with programs, to obtain users' recommendations for acquisitions, and to announce new acquisitions. Periodically issue a newsletter printed from the conference's electronic "proceedings."

6. INITIAL PRODUCTS FOR THE PROTOTYPE SOFTWARE EXCHANGE

Portable:

1. The VPI general least squares fitting program, with MSU's alternate search techniques and surface checker added to make it more versatile.
2. Paris, MSU/LASL, and Stony Brook NN potential generators.
3. Schrödinger equation solver for bound, scattering, coupled states.
4. Coulomb wave function generator for all ρ , η .

Not so portable:

5. Schrödinger equation solver with option of PARIS, MSU/LASL, HJ, Reid (SC) potential; bound state parameters, phases, quasiphases, on- and off- shell amplitudes; tables of same, comparison to data.
6. Relativistic NN model calculator: Noble, MSU/LASL 1π + 2π -exchange.
7. SCHOONSCHIP, REDUCE, SMP: new versions of these highly regarded formal manipulators, especially good for Feynman diagram calculations: the single software capability most often requested by nuclear theorists in the "pions, kaons, light nuclei" part of the NSAC poll.
8. PIPIT: highly regarded DWBA generator for pion-nucleus scattering.
9. Cooperatively evaluated NN data bank, 0-1200 MeV (data from other processes to be added as feasible).

Available on-line now:

1. Paris potential, entirely menu-driven.
2. SCHOONSCHIP, with laser-printed 100 page tutorial.
3. Schrödinger equation solver with Paris potential.
4. Nuclear physics preprints received at NSCL, separated into 12 topical categories, with documentation data and abstracts, on Telenet dial-in and with a retrieval system.

To be available in upcoming contract period:

(all other programs mentioned above)

REPORTS ISSUED, 4/6/81 - 12/31/81

C00-10516-10: "Nucleon-Nucleon Theory and Phenomenology: A
Program Report and Renewal Proposal" (this document)

PROPOSED BUDGET

June 1, 1982 - May 31, 1983A-II(a) REIMBURSABLE OR COST SHARING PORTION1. Salaries and WagesScientific Discipline Personnel

P. Signell, Princ. Invest., 100% of time, 5 wks. SU 1981, @\$1170/wk	\$ 5,850
---	----------

Graduate Assistant, 50% of time for 12 months @\$660/mo.	\$ 7,920
---	----------

Undergraduate Assistant, 25% of time, 12 mo @\$55/wk	\$ 2,860
---	----------

Support Personnel

G. Kales, Software Systems, Evaluation and Documentation, 100% of time for 12 mo. @\$1500/mo.	\$18,000
---	----------

F. Freiheit, Data Base Administrator and Data Analyst, 15% of time for 12 mo. @\$500/mo.	\$ 6,000
--	----------

J. Hanes, Secretary, 20% of time for 12 mo. @\$210/mo.	\$ 2,520
---	----------

TOTAL SALARIES AND WAGES	<u>\$43,150</u>
--------------------------	-----------------

2. Fringe Benefits

7% of Pr. Inv. S&W; 20% of DBA, SED, CSA, Secr.	\$ 5,710
--	----------

3. Misc. Costs

Supplies and Services (incl. telephone and replacement parts and service for text pro- cessor/smart terminal.)	\$ 3,900
---	----------

Travel	\$ 1,600
--------	----------

Publication	\$ 2,100
-------------	----------

Computing	\$11,000
-----------	----------

	<u>\$18,600</u>
--	-----------------

Subtotal, direct costs	\$67,460
------------------------	----------

4. Indirect Costs

41% of total direct costs without
equipment, negotiation dated
7/15/81, between HHS and Michigan
State University

\$27,660

TOTAL \$95,120

Time Commitment

The time commitment of the Principal Investigator will be 45% during the Academic Year portions of the contract period, contributed by Michigan State University. The P.I.'s time commitment during the designated period of summer 1982 is 100%, as noted in the Budget.

U. S. ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION
UNIVERSITY-TYPE CONTRACTOR'S RECOMMENDATION FOR
DISPOSITION OF SCIENTIFIC AND TECHNICAL DOCUMENT

(See Instructions on Reverse Side)

1. ERDA REPORT NO. COO-10516-6	2. TITLE Nucleon-Nucleon Theory and Phenomenology: A Progress Report and Renewal Proposal
-----------------------------------	---

3. TYPE OF DOCUMENT (Check one):

- ☒ a. Scientific and technical report
☐ b. Conference paper:

Title of conference _____

Date of conference _____

Exact location of conference _____

Sponsoring organization _____

- ☐ c. Other (Specify) _____

4. RECOMMENDED ANNOUNCEMENT AND DISTRIBUTION (Check one):

- ☒ a. ERDA's normal announcement and distribution procedures may be followed.
☐ b. Make available only within ERDA and to ERDA contractors and other U. S. Government agencies and their contractors.

5. REASON FOR RECOMMENDED RESTRICTIONS:

6. SUBMITTED BY: NAME AND POSITION (Please print or type)

Peter Signell, Professor of Physics

Organization

Michigan State University

Signature

Date

12/29/81

FOR ERDA USE ONLY

7. ERDA CONTRACT ADMINISTRATOR'S COMMENTS, IF ANY, ON ABOVE ANNOUNCEMENT AND DISTRIBUTION RECOMMENDATION:

8. PATENT CLEARANCE:

- ☐ a. ERDA patent clearance has been granted by responsible ERDA patent group.
☐ b. Report has been sent to responsible ERDA patent group for clearance.
☐ c. Patent clearance not required.

PUBLICATION
BY AEC
AUTHORIZED ☐

NOTICE OF RESEARCH PROJECT
SCIENCE INFORMATION EXCHANGE
SMITHSONIAN INSTITUTION
U.S. ATOMIC ENERGY COMMISSION

SIE NO.

AEC CONTRACT NO

SUPPORTING DIV. OR OFFICE: Erloee Ritter, Nuclear and High Energy Physics

NAME & ADDRESS OF CONTRACTOR OR INSTITUTION: (State the division, department, or professional school, medical, graduate or other, with which this project should be identified.)

Department of Physics
Michigan State University
East Lansing, MI 48824

TITLE OF PROJECT:

"Nucleon-Nucleon Theory and Phenomenology"

NAMES, DEPARTMENT, AND OFFICIAL TITLES OF PRINCIPAL INVESTIGATORS AND OTHER PROFESSIONAL SCIENTIFIC PERSONNEL: (not including graduate students) engaged on the project, and fraction of man-year devoted to the project by each person

Peter Signell, Physics Dept., Professor of Physics
Principal Investigator

NO. OF GRADUATE STUDENTS ON PROJECT: _____ NO. OF GRADUATE STUDENT MAN-YEARS: _____

SUMMARY OF PROPOSED WORK: (200-300 words, omit Confidential Data). Summaries are exchanged with government and private agencies supporting research, are supplied to investigators upon request, and may be published in AEC documents. Make summaries substantive, giving initially and for each annual revision the following: OBJECTIVE; SCIENTIFIC BACKGROUND FOR STUDY; PROPOSED PROCEDURE; TEST OBJECTS AND AGENTS.

This work is to both attack a number of outstanding problems in the free nucleon-nucleon interaction, problems whose solution impinge on many theoretical calculations and experiments in nucleon physics, and to provide coordination with D.O.E.'s other NN groups.

RESULTS TO DATE:

(i) new phase analyses of nucleon-nucleon data in the 0-400 MeV region, showing the energies at which various high-L phases are as given by theory; (ii) delineation of the P-wave scattering lengths and effective ranges; (iii) verification of 3,300 data in the on-line NN data bank, including bibliographic data and warnings on usage; (iv) parts of new NN potential for nuclear calculations with improved theory and phenomenology.

BUDGET	PROGRAM CATEGORY NO.
PRIMARY	
SECONDARY	

Signature of Principal Investigator

DATE: 12/29/81

INVESTIGATOR-DO NOT USE THIS SPACE