Final Technical Report
April 1, 1994- September 30, 1996

MEDIUM ENERGY MEASUREMENTS OF N-N PARAMETERS

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Sponsored by the U.S. Department of Energy
by
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Abstract

This document is a final technical report describing the accomplishments of the medium/high energy nuclear physics research program “Medium Energy Measurements of N-N Parameters” at the University of Texas at Austin, and supported by the U.S. Department of Energy through grant No. DE-FG03-94ER40843 for the time period April 1, 1994-September 30, 1996.

Our research program had four main thrusts, only one of which can be considered as measurements of N-N parameters: (1) Finishing the data analyses associated with recent LAMPF and TRIUMPF N-N experiments, whose overall purpose has been the determination of the nucleon-nucleon amplitudes, both for isospin 0 and 1 at medium energies; (2) continuing work on BNL E871, a search for rare decay modes of the KL; (3) work on the RHIC-STAR project, an experiment to create and study a quark gluon plasma and nuclear matter at high energy density; (4) beginning a new AGS experiment (E896) which will search for the lowest mass state of the predicted strange di-baryons, the Ho, and other exotic states of nuclear matter through nucleus-nucleus collisions.

The group’s graduate students were David Ambrose, Wayne Betts, Patrick Coffey, and Jaw-Luen Tang. Of these, Wayne Betts and Patrick Coffey have graduated with M.Sc. degrees. David Ambrose recently received his Ph.D. (Co-Chairmen Peter Riley and Jack Ritchie); his dissertation research involved rare kaon decays in BNL E871. Jaw-Luen Tang expects to complete his dissertation research by the end of 1998; his dissertation is based on RHIC Experiment E896 (Co-Chairmen Peter Riley and Jerry Hoffmann).
UNIVERSITY OF TEXAS NUCLEAR PHYSICS GROUP

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Physics Summary:

The Physics areas addressed by our nuclear physics research group were the following:

* Elastic N-N (pp and np) nucleon-nucleon measurements at LAMPF, to determine the isospin-0 and -1 amplitudes at medium energies.

* Inelastic pion production studies at LAMPF and at TRIUMF, to understand the inelasticities in both I = 0 and 1 at medium energies.

* Rare kaon decay measurements at BNL, to obtain a better understanding of the fundamental electroweak interaction (E871 at BNL).

* Relativistic heavy ion measurements at the RHIC facility at BNL (STAR), to create and study the quark gluon plasma, and to measure and study the properties of nuclear matter at high energy density.

With the closing down of the Nucleon Physics facility at LAMPF, our emphasis shifted to the last two research areas: the rare kaon decay, and an increasing level of activity with the STAR experiment. Both of these activities are centered at BNL.
NARRATIVE

Until 1990, nearly all of the work of the Medium-Energy nucleon-nucleon (N-N) physics program of the University of Texas at Austin was associated with nucleon-nucleon (N-N) research carried out at the Nucleon Physics Laboratory (NPL) of the Los Alamos Meson Physics Facility (LAMPF). The overall aim of our N-N experimental program was the determination of the nucleon-nucleon amplitudes, both for isospin 0 and 1, at medium energies. The required data included both elastic and inelastic experiments, and in addition the measurement of polarization and polarization transfer parameters. The aims of our program were achieved, at least for the elastic channels.

In 1989 we began participation in a rare kaon decay experiment at Brookhaven, BNL E791, an experiment designed to study the fundamental electroweak interaction. After the completion of E791 in 1992, we became involved in E871, a second generation rare kaon decay experiment. E871 completed an engineering test run during the summer of 1993, and took data during 1995 and 1996. We also became members of a proposed experiment, STAR, (Solenoidal Tracker at RHIC) to be carried out at the Relativistic Heavy Ion Collider facility, RHIC, at BNL.

We had hoped to extend our LAMPF elastic pp and np elastic work to include a comprehensive study of the inelastic N-N channels. However, in 1992, a LAMPF experiment, E1097, designed to study the np→ppπ⁻ reaction, was terminated after we had fabricated and tested the detector, but before data acquisition. Consequently we increased our participation in the rare kaon experiment at BNL, E871. Subsequently our research emphasis shifted completely to the BNL rare kaon decay measurement, E871, and to STAR.

Our final nucleon-nucleon experiments consisted of the following:

(1) Forward angle (n,p) analyzing power measurements. By extending our analyzing-power measurements to forward angles, we were able to tie together the normalization of the forward- and backward-angle peaks and also tie the np to the pp normalization via quasifree measurements. Analyzing-power data are also a sensitive probe of the higher partial waves which are sensitive to isospin-0 inelasticity. These measurements were carried out during the summer of 1993.

(2) n-p inelastic polarization measurements. We carried out a TRIUMF experiment designed to measure the cross section and analyzing powers for the reaction np→ppπ⁻ at a neutron energy of 440 MeV, and planned, until late fall, 1992, to carry out the same measurements at the higher LAMPF energies using a new cylindrical drift chamber surrounding the target. The Ph.D. dissertation of Mark Bachman was based on the TRIUMF experiment (E372).

The forward angle (n,p) analyzing power measurements, completed during the summer of 1993, provided the cross calibration needed to tie together the normalization of different data sets, and resolved an existing problem of the divergence of the energy-dependent $A_{NO}$ fits from the single-energy fits above 500 MeV. The major remaining weakness is with the inelasticities. Although the TRIUMF experiment (E372) has been successful, the higher energy np→ppπ⁻ spin-dependent measurements proposed for LAMPF are still badly needed to help resolve our very limited knowledge of I=0 inelasticities. With the closing down of the LAMPF N-N program, however, we do not anticipate new experimental data relating to this problem within the next several years. With the analysis and publication of our forward angle (n,p) analyzing power data, the determination of the
elastic isospin-1 and -0 amplitudes in the energy range 500-800 MeV can be considered complete.

In the Minimal Standard Model (MSM) the decay $K_L^0 \rightarrow \mu e$ is forbidden by conservation of electron and muon additive quantum numbers. Its observation would be the first direct evidence of physics beyond the MSM. The decays $K_L^0 \rightarrow \mu \mu$ and $K_L^0 \rightarrow e e$ are permitted in the MSM, but are highly suppressed. $K_L^0 \rightarrow e e$ was first observed (4 events) in BNL E871. The branching ratio for this process appears to be in reasonable agreement with MSM predictions.

BNL E791, a high sensitivity search for $K_L^0 \rightarrow \mu e$ and $K_L^0 \rightarrow e e$, completed data-taking at the Alternating Gradient Synchrotron facility (AGS) of the Brookhaven National Laboratory in 1990, the year in which our group joined the experiment. The E791 spectrometer provided precise tracking with good (redundant) particle identification. Very high rate capability was achieved using custom built front-end electronics, a large parallel readout architecture, and a multi-level trigger system utilizing SLAC 3091/E emulators. The single event sensitivity to the decay $K_L^0 \rightarrow \mu e$ achieved by E791 was $<3.3 \times 10^{-11}$. Subsequently, a new collaboration, with substantial overlap with E791, was formed to perform a new search for $K_L^0 \rightarrow \mu e$ and similar modes. A new proposal was written, E871, “A New Search for Very Rare $K_L$ Decays,” (Spokesmen; W. R. Molzon, University of California, Irvine, S. G. Wojcicki, Stanford, and J. L. Ritchie, University of Texas). The aim of BNL E871 was to build on the experience of E791, the most sensitive kaon decay experiment performed to date, and to re-use some of the E791 equipment. Through increased acceptance, higher rate-handling capability, and key improvements in several detector systems, the experiment reached a single event sensitivity of approximately $5 \times 10^{-12}$ (to be published). A few $K_L^0 \rightarrow e e$ decays were also observed (to be published), consistent with Standard Model predictions, along with about 7,000 $K_L^0 \rightarrow \mu \mu$ decays (to be published). The experiment was made possible because of the increased beam flux made available by the AGS Booster.

The two physics Ph.D. graduate students who previously had been working on LAMPF E1097, David Ambrose and Patrick Coffey, participated in E871.

In 1992 we joined a large collaborative group working on the RHIC experiment STAR (Solenoidal Tracker at RHIC) at BNL. The physics goals of the RHIC project are to create and study a new phase of nuclear matter - the quark gluon plasma, and to study in detail the properties of nuclear matter at high energy density. For the next several years this project will emphasize the design and fabrication of a very large, complex collider detector. This STAR detector is a combination of a silicon vertex tracker (SVT), a Time Projection chamber (TPC), a set of trigger scintillators, and time of flight (TOF) counters. There are also an external TPC (XTPC) and some MWPCs. A graduate students, Jaw-Luen Tang is carrying out his Ph. D. dissertation research on this experiment. Further, a major effort is needed for simulation studies that would establish the detectability of the direct gammas and the associated jets within the plethora of tracks generated in the high luminosity environment anticipated for RHIC.
Table 1: The approximate time scale for our research projects.

Table 1 shows the expected time scale for our research projects. The transition from our LAMPF and TRIUMF N-N experimental program to rare kaon decay and relativistic heavy ion experiments at BNL is apparent. AGS P896 is a search for a short-lived $H_0$ dibaryon, short lived strange matter, and the investigation of hyperon production in 11.6 A GeV/c Au-Au collisions. The $H_0$ search is important not only because physics research at RHIC-STAR will not begin until about the year 2000, but also because P896 may well serve as a testing ground for some of the components of the STAR detector system.
PUBLICATIONS


PERSONNEL

1. David Ambrose: (Graduate Student) AGS E871 (Rare Kaon Decay).
2. Wayne Betts: (Graduate Student) STAR, (TPC assembly at Berkeley).
3. Patrick Coffey: (Graduate Student) AGS E871, (graduated fall, 1994).
4. George Glass: (Research Scientist) LAMPF 1293; STAR EMC (Will leave the group effective March 31, 1995).
5. James McDonough: (Post-Doctoral Research Fellow, 1/2 time) AGS E871 (Will leave the group effective June 30, 1995)
6. P. J. Riley: (Professor) TRIUMF E372; AGS E871; STAR; AGS E896.
7. Jaw-Luen Tang: (Graduate Student) STAR TPC software development; AGS E896 (software development).