

# Institute of Nuclear and Particle Physics

2001 - 2006

Institute of Nuclear and Particle Physics  
Department of Physics and Astronomy  
Ohio University  
Athens, OH 45701  
*<http://inpp.ohiou.edu>*

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Prepared for:

College of Arts and Sciences  
Charlotte Elster, Director

## CENTER/INSTITUTE SUMMARY

Center/Institute: Institute of Nuclear and Particle Physics

Director: Charlotte Elster  
Department of Physics and Astronomy  
College of Arts and Sciences

Affiliated Faculty: Carl Brune, Associate Professor of Physics  
Daniel Carman, Associate Professor of Physics  
Charlotte Elster, Professor of Physics  
Steven Grimes, Distinguished Professor of Physics  
Kenneth Hicks, Professor of Physics  
David Ingram, Professor of Physics  
Daniel Phillips, Associate Professor of Physics  
Madappa Prakash, Professor of Physics  
Julie Roche, Assistant Professor of Physics  
Louis E. Wright, Professor of Physics  
Mark Lucas, Associate Professor of Physics (Group II)  
Paul King, Research Assistant Professor of Physics  
Thomas Massey, Research Assistant Professor of Physics

Charles Brient, Associate Professor of Physics, Emeritus  
Roger Finlay, Distinguished Professor of Physics, Emeritus  
David Onley, Professor of Physics, Emeritus  
Jacob Rapaport, Distinguished Professor of Physics, Emeritus

### **Mission:**

The mission of the INPP is to promote activities in theoretical and experimental subatomic physics, and to pro-actively educate graduate and undergraduate students in these fields. The faculty and students in the INPP have access to the most sophisticated particle accelerator in the State of Ohio, and in addition, have access to national and international accelerators using a variety of probes at low and high energies.

### **Future Activity:**

In addition to on-going research activities, the INPP will (a) continue to support the URP "Structure of the Universe" program, especially through assistance in providing start-up funds for new faculty; (b) support the extension of the graduate program to include degrees based on Applied Nuclear Physics; (c) use modest funds to leverage larger external grants from sources such as the DOE and NSF; (d) provide partial support for 1 to 3 postdoctoral research fellows; (e) enhance the intellectual atmosphere for graduate and undergraduate students by organizing seminars and field trips.

**Awards (2001-2006):** External Grants \$8,378,000

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# 1 Mission Statement

The Institute of Nuclear and Particle Physics was established at Ohio University in 1991 to bring coherence to the several successful, but diverse nuclear and particle physics activities taking place within the Department of Physics and Astronomy, and to coordinate the activities of both, theoretical and experimental subatomic physics.

The Institute is a perfect vehicle for promoting and supporting research in theoretical and experimental subatomic physics, pro-actively educate graduate and undergraduate students in these fields of study, sponsor joint seminars, host visiting scientists, and provide matching funds for new initiatives undertaken with federal agencies and national laboratories.

Activities within the Institute include:

- Support of the activities within the URP program “Structure of the Universe” by allocating funds for refurbishing the Edwards Accelerator Laboratory and assisting in providing startup for the two faculty hired within this initiative.
- Study of exotic nuclei that are unusually rich in neutrons with applications to astronomy such as nuclear reaction rates in stars and nucleosynthesis in the early history of the universe. Study of physical reactions within supernova explosions.
- Study of the quark substructure of the proton and neutron through experiments at the Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News, VA, using high-energy beams of electrons and photons.
- Theoretical studies on properties of protons, neutrons and light nuclei as revealed by exposing them to beams of electrons, photons, protons and neutrons at different energy scales.
- Inviting researchers to the Department of Physics and Astronomy and the Edwards Accelerator Laboratory to give scholarly talks as part of the INPP seminar series and to exchange research ideas.
- Support a lunch-time journal club for students and postdocs within the INPP to discuss current research in Nuclear Physics.
- Provide matching funds for initiatives with funding agencies and national laboratories, with the goal to leverage larger amounts of external research funding.
- Provide matching funds for postdoctoral researchers, graduate and undergraduate students.

## 2 Brief History

The Institute of Nuclear and Particle Physics was established in 1991 with the goal of enhancing interactions among faculty and students in the Department of Physics and Astronomy conducting research in these areas. Before 1991, nearly three decades of successful programs in nuclear physics research and graduate education had brought significant national and international recognition to Ohio University. Some highlights are:

- The first Ph.D. in the Department of Physics and Astronomy, 1963.
- Awarding of 85 Ph.D. degrees in Physics during 1963-1991.
- Construction of the Edwards Accelerator Laboratory, 1969.
- Sustained external research support from DOE and NSF.
- Three Distinguished Professors (Lane, 1972; Rapaport, 1981; Finlay, 1991).

The Edwards Accelerator Laboratory currently houses the highest-energy particle accelerator in the State of Ohio. This facility was the center of the nuclear experimental research during the 1970's and 1980's. Its unique experimental capabilities, in particular its neutron detection equipment, played a special role in nuclear experiments of that period. This special role has continued to pay dividends today as evidenced by several contracts for use by outside researchers, e.g. Lawrence Livermore National Laboratory (LLNL) and the National Institute of Standards and Technology (NIST). Currently, the role of the accelerator has been enhanced by experiments that shed light on the formation of the elements in the early universe. This role will likely be enhanced further in the future as it has the opportunity to become a part of the research and development efforts of the proposed National Rare Isotope Accelerator (RIA). Toward this goal, we have recruited a new faculty in this area.

Currently, the accelerator is being used not only for research in nuclear physics, but also for condensed matter investigations of the surface properties of thin films. This research has potential applications in the semiconductor industry. These studies are undertaken at the Keck Thin-Film Laboratory (housed within the Edwards Accelerator Laboratory), which was established to pursue this work with a grant of \$400,000 from the Keck Foundation. In addition, the accelerator is used by faculty from Ohio State University for modeling cancer therapy. This research cannot be carried out anywhere else in the State.

Concomitantly with the progress being made at the Edwards Laboratory, the research efforts of the INPP in experimental nuclear physics have broadened. The INPP members now work at a number of national and international "intermediate" and "high" energy

facilities. A large part of INPP's experimental effort is located at the Thomas Jefferson National Accelerator Facility (TJNAF), where the beam consists of electrons or photons with energies roughly a factor 100 larger than that at the Edwards facility. These national facilities allow the investigation of the internal structure of the nucleus – and the structure of neutrons and protons themselves – at very small distances. Research by faculty and students at TJNAF, Brookhaven National Laboratory, and SPring8 in Japan have been possible largely because INPP encourages the group effort that is necessary to support large-scale organized research programs at these facilities.

Another important thrust of the INPP faculty in experimental nuclear physics is directed toward experiments involving short lived exotic nuclei. This research is carried out at the Holifield Radioactive Ion Beam Facility (HRIBF) at the Oak Ridge National Laboratory and the ISAC Radioactive Ion Beam Facility at TRIUMF, Canada, the Grand Accelérateur National D'Ions Lourds (GANIL), France, and the Berlin Hahn-Meitner Institute, Germany. In the future, the INPP faculty will also get involved in experimental efforts at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University. In summary, the INPP faculty carry out cutting-edge research not only on campus, but also at several national and international facilities.

Similar to the experimental efforts, the theory program has grown over the years and now has considerable breadth in its research scope. In the beginning, the theoretical investigations within the institute were concentrated on exploring the structure of nuclei using electromagnetic probes. Successful research in this area was later complemented by efforts to understand the structure of the lightest nuclei with hadronic probes, i.e. protons and neutrons, through ab-initio calculations as well as those utilizing the framework of effective field theories. During the last five years, new directions in nuclear astrophysics, and, in hot and dense matter, have been forged to complement the above efforts. These initiatives now allow for a theory group with extensive research breadth. Ohio University's theory group ranks among the ten best funded nuclear theory groups in the country.

## 3 Current Activities

### 3.1 Number and Role of Faculty and Students

The faculty at the INPP encompass a broad spectrum of research in nuclear physics. Activities include both theoretical and experimental investigations on-campus as well as off-campus. Roughly speaking, there are three different groups within the INPP: (i) Low-Energy Experiments, (ii) Medium-Energy Experiments, and (iii) Theoretical Nuclear and Particle Physics and Astrophysics.

The research of the Low Energy experimental group is concerned with the study of exotic nuclei and nuclear reactions which are important for the understanding of the formation of nuclei in astrophysical processes. These experiments are partly carried out in the Edwards Accelerator Laboratory and partly at facilities like HRIBF at the Oak Ridge National Laboratory, the GANIL facility in France, and TRIUMF in Canada. This group, consisting of Profs. Brune, Grimes, and Massey, typically supports 4 to 5 Ph.D. students and 1 to 2 postdoctoral researchers. In Fall 2007, a new faculty member, Prof. Schiller, (the last of the URP hires) will join the Low Energy group. Prof. Schiller brings a new dimension, namely the study of exotic nuclei at somewhat higher energies (as provided by the NSCL at MSU or at the Argonne National Laboratory), which allows the study of nuclei far off the line of stability. The knowledge about these nuclei provides insight into the creation of heavy elements during the formation of the universe.

The research of the Medium Energy experimental group is conducted mainly at TJ-NAF. Additionally, this group participates in experiments at SPring8 in Japan and the LEGS facility at Brookhaven. This group underwent significant changes over the last 5 years. Prof. Allena Opper left Ohio University in 2005 to take up a position at George Washington University. This position was open for one year. In September 2006, Julie Roche and her husband, Paul King, joined the faculty. Prof. Daniel Carman was hired in 2006 as Staff Scientist at TJNAF and resigned from Ohio University in March 2007 after being on leave since Summer 2006. At the earliest, a replacement for him can be started in the academic year 2008-09. In both cases, Opper's and Carman's reasons for leaving Ohio University were personal issues beyond our control. Both are excellent researchers and are well known in the field, and their departure left gaps in the INPP faculty, which are now only partially filled. Normally this group supported 1 to 3 students and 1 to 3 post-doctoral researchers. However, at present this number is down for obvious reasons. Over the last 5 years, Profs. Hicks and Carman studied properties of proton excitation with electromagnetic probes, Prof. Opper studied parity violation in strong and weak interactions. The recently hired Profs. Roche and King study properties of the weak-interaction through parity-violating electron scattering.

The Nuclear Theory group consists of Profs. Elster, Phillips, Prakash, and Wright.

Prof. Wright took early retirement in 2005, and his position was replaced by Prof. Prakash in September 2005. Since then, the research areas of the group significantly expanded. The study of the lightest nuclei probed with protons, neutrons, and electromagnetic probes has been extended to include objects of astrophysical scales as encountered in the physics and astrophysics of supernova explosions and the evolution of neutron stars from their birth to old age. The theory group supports about 4 Ph.D. students on average and 1 to 2 postdoctoral researchers. A list of current graduate students is given in Appendix A and that of postdoctoral researchers in Appendix C.

## **3.2 Meeting Objectives**

### **3.2.1 The University Research Priority: Structure of the Universe**

The University Research Priority (URP) project entitled “The Structure of the Universe: From Quarks to Superclusters” was chosen as Ohio University’s highest priority out of 20 URP proposals selected for this competition held in 2003-04. The science issues addressed in this proposal lie in the interface between nuclear/particle and astrophysics. Faculty and students of the INPP and the Astrophysical Institute (ApI) collectively decided that the time was ripe to deepen their involvement with research in this emerging area. This synergistic proposal tackles questions about the interactions among atomic nuclei and subatomic particles that determine the composition of the cosmos and drive the birth, life, and death of stars, the large-scale structure of the Universe, and the formation and evolutions of galaxies.

The first step in implementing the URP was the hire of Prof. Prakash, who significantly expanded the research scope of the nuclear theory group as well as its nationwide standing. The Ohio University nuclear theory grant is now among the ten largest in the country. Combined seminars of the ApI and INPP bring top researchers to Ohio University. The last hire of the URP, Dr. Andreas Schiller from Michigan State University, will join the faculty in September 2007. Schiller’s research interest and plans in nuclear astrophysics and radioactive beam physics will complement and enhance the visibility and strength of the low-energy experimental group in INPP. Although details of the implementation of the URP are not subject of this review, the INPP commitment to the URP proposal significantly influenced and will continue to influence the research directions of the INPP.

### **3.2.2 Students, Postdoctoral Researchers and Visiting Scientists**

An important goal of the INPP is the education and training of students (undergraduate and graduate) as post-doctoral fellows for careers in advanced technical professions. Whereas some take up academic careers, many work in industry in advanced computing,

medical physics (including radiation therapy), and private research corporations. A list of graduates since 1993, including their current positions, are given in Appendix B.

Matching funds have been provided by the INPP to support the salary of postdoctoral fellows. A list of postdoctoral fellows with the INPP, together with their current positions, is given in Appendix C. Compared to the previous five-year cycle, the number of postdoctoral fellows with the INPP has more than doubled. Faculty of the INPP introduced a student lunch seminar component to the regular nuclear seminar to provide a forum for introducing and discussing a broad range of current research topics in nuclear physics. The INPP supports this student seminar by providing lunch for the students. A more detailed discussion, together with the student enrollment in this seminar course, is contained Appendix A. The INPP also matched other support for a few undergraduate research projects.

The role of visiting scientists is twofold. First, they exchange ideas with our faculty and students. Second, their close association with Ohio University raises the national profile of the INPP. In addition to the quarterly seminar series sponsored entirely by the INPP, the INPP has provided partial support for 16 visiting scientists. INPP was the major sponsor (together with TJNAF, George Washington University, and the College of Arts & Sciences) of a workshop on “*Dynamical Approaches to Meson Photo-Production*” in May 2003. This workshop attracted about 30 scientists to Ohio University. It is clear that efforts like this have raised the profile of the INPP within the nuclear physics community. A list of visiting scientists is given in Appendix D.

### **3.2.3 Research Highlights**

The INPP is blessed with faculty who are leaders in their respective research fields. The faculty, with postdoctoral fellows and graduate students, have authored over 300 publications in refereed journals during the past five years. Research in the medium-energy experimental group received considerable attention in the nuclear and particles physics communities. The most cited OU’s research papers were concerned with the search for the exotic pentaquark, the observation of charge symmetry breaking in the fusion of a neutron and a proton producing a pion, and the determination of strange quark contributions in the polarization of Lambda-hyperons. For brevity, the research highlights of the last five years are described in more detail in Appendix E.

### **3.2.4 National/International Activities of INPP Faculty**

One of the long term goals laid out in the Vision Ohio document is the increase of Ohio University’s visibility in the national arena. The national and international visibility of the INPP, the Department of Physics and Astronomy, and Ohio University can be elevated

through leadership of its faculty in national/international organizations, leadership in conferences, and participation in national/international review panels. INPP members have been very active and successful in this regard during the last five year period. A selected list of high profile activities is given Appendix F. One of the stated goals of the INPP in its last five-year review was to host a conference/workshop. This goal was achieved by hosting a workshop on “*Dynamical Approaches to Meson Photo-Production*” in May 2003. Two faculty of INPP were elected as Fellows of the American Physics Society (APS); Prof. Charlotte Elster in 2001 and Prof. Ken Hicks in 2005. Only about 1% of all members of the APS are Fellows. Prof. Steve Grimes was elected to be a Distinguished Professor at Ohio University in 2001.

### **3.2.5 The Edwards Accelerator Laboratory**

The primary nuclear physics experimental facility at Ohio University is the 4.5-MV tandem van de Graaff accelerator located in the Edwards Accelerator Laboratory. The laboratory has been featured in the article *Physics in the Fast Lane: The John E. Edwards Accelerator Laboratory* in “Ohio Today”, which is included as Appendix G. As part of the URP enhancement of our facilities, \$100,000 have been allocated over 5 years for upgrading the Edwards Accelerator Laboratory. Half of this amount is provided from the INPP funds. For the last 2 fiscal years, the INPP devoted \$10,000 each year for upgrades. A detailed description of upgrades is given in Appendix F together with other expenditures the INPP incurred for equipment purchases, technical improvements of data acquisition and the operation of the accelerator.

## 4 Proposed Future Activities

The INPP will continue to support activities that have proved successful over the past years. Examples include

- The Nuclear Seminar Series, which brings researchers to Ohio University
- Support of collaboration visits of researchers and scientists with INPP faculty
- Partial support for postdoctoral researchers to leverage additional external funding
- The Student Nuclear Lunch Seminars, which brings together students in experimental and theoretical nuclear physics and provides a forum to discuss a broad range of current research topics in nuclear physics.
- Match of Research Challenge Awards

The reputation of a group is built over time, and the national/international visibility of a scientist (or a group of scientists) can carry some weight in funding decisions. A lively visitor program (seminar speakers and collaborators) helps the INPP to maintain and grow connections with the national and international communities of nuclear physicists. In addition, the visitor program enhances the intellectual atmosphere for graduate and undergraduate students by providing students opportunities to discuss cutting-edge research with outside experts. The visitors experience the quality of our institute and Ohio University on site. A list of visiting scientists is given in Appendix D.

Another venue to enhance the national profile of the INPP is to host conferences and workshops. In 2003, Ohio University, the College of Arts and Sciences and the INPP hosted a workshop on “*Dynamical Approaches to Meson Photo-Production*”. Given its success, we want to establish the tradition of hosting a conference or workshop every few years in order to consolidate our visibility. Our next plan is to put forth a proposal to the Division of Nuclear Physics of the APS to host the National Nuclear Physics Summer School in the summer of 2010. This annual summer school brings together about 50 top students and postdoctoral researchers (from all over the world) in their early careers for 2 weeks. Lectures on a variety of current topics in nuclear physics are presented by renowned researchers in the field. At present, Prof. Charlotte Elster serves as member of the National Advisory Committee which evaluates proposals and selects sites for these summer schools. Her term ends in 2008. Thus, the perfect timing is for us to submit a proposal in 2009 to host the summer school in 2010. The majority of the funding will be provided by a grant from the National Science Foundation; however, it is customary and necessary that hosting institutions co-sponsor the summer school. The INPP will certainly contribute its share.

In response to a call for proposals from the Graduate Education and Research Board (GERB) at Ohio University in Fall 2006, the INPP and the Department of Physics and Astronomy proposed a graduate program in applied nuclear physics. Though this proposal did not receive university funding, the INPP, with help from the VP for Research and the College of Arts and Sciences, decided to go forward with these ideas as they are very timely, strengthen the INPP and the department, and fit perfectly with the goals laid out in the Vision Ohio document. proposal's motivation stems from the recognition that there is a clear national need in areas of national security, medical diagnostics and energy. These needs can be met through a graduate program in applied nuclear physics.

The Edwards Accelerator with its associated infrastructure and staff is well poised to develop this extension of our graduate program and its associated research program to serve the national need. We will be able to attract new graduate students in addition to obtaining new external research funds to support the program. The INPP faculty have submitted a proposal in January 2006 advertising this research area. The INPP has committed modest matching funds. It makes perfect sense for the INPP to engage in this endeavor, especially since its faculty continue to have a very successful research program using our own accelerator. With the closure of many university based accelerators elsewhere, we have a unique laboratory in which such a program has a high probability of success. The INPP is well prepared to help this program to a successful start.

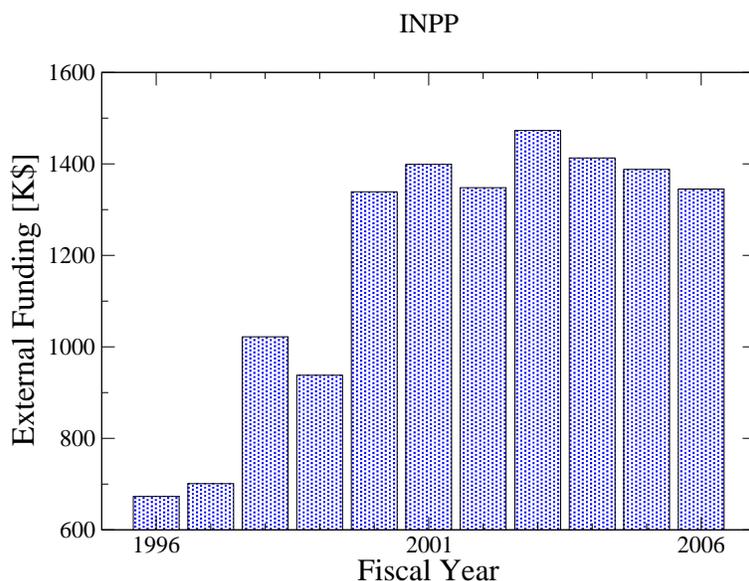
A program in applied nuclear physics can also prove to be attractive for undergraduate summer interns. The INPP has a long tradition of giving part-time support to Summer Undergraduate Internships. This tradition has not been followed during the past 5 years. One reason for this lapse may be faculty summer travel and work schedules. We hope to revive this tradition by instituting Summer Internships for first year graduate students. This move is stimulated by changes in the Departments policy on doctoral candidacy.

The University Research Priority "Structure of the Universe" program is in its last 2 years of university support. The INPP commitments to this URP will continue, as will commitments to proven successful initiatives and to efforts that may need support beyond the university cut-off date.

The future is difficult to predict, and some INPP funds should be reserved for unforeseen new ideas and initiatives. Sufficient flexibility must prevail to exploit new windows of opportunity.

## 5 Funding Commitments

The overhead generated by the external grants of the INPP faculty is the sole source of funding for the Institute. The INPP receives no direct funding from the College of Arts and Sciences or the Vice President of Research, apart from those involving competitive programs (Research Challenge, 1804 Fund, OUPD, etc.) that are available to all faculty. Over the last 5 years, the INPP faculty have received a total of \$60,000 through these programs. The majority of the external funds come from the U.S. Department of Energy and the National Science Foundation.



**Fig.1:** Total amount of external funding (in thousands of dollars) received by the INPP faculty over the last 10 fiscal years. The lower value of the y-axis was chosen for historical reasons. The INPP started in 1991 with a grant of \$678,000. Till 1997, the grant amount has been nearly the same.

It is worthwhile to note that the total external funding of the INPP faculty was fairly constant during the review period (2001-2006) with an average of \$1,394,000 *despite* all changes in the faculty during this time. Louis Wright took early retirement, and Madappa Prakash started in September 2005 as full professor in the Department of Physics and Astronomy. Prakash was fully funded by DOE from the beginning. Allena Opper departed Ohio University in Spring 2005 to take up a position as Associate Professor at George Washington University. This position was filled by Julie Roche, who started in September 2006. Note that Julie Roche's position is a bridge position between Ohio University and TJNAF, in which 1/3 of her salary is provided by TJNAF for 3 years. Daniel Carman has recently resigned from Ohio University to take up a position as Staff Scientist at TJNAF. The Department of Physics and Astronomy and INPP expect to be able to

replace Carman. Andreas Schiller has accepted a position in our department and will join the INPP in September 2007. We expect that he will attract his own funding within a year.

In summary, the INPP faculty have managed to keep the grant amount fairly constant over the last five years despite a little over 20% change within the INPP faculty. Once the newly hired faculty firmly establish their research programs, an increase in the total grant amount is a realistic outlook. The establishment of an applied nuclear physics program as discussed in the previous section is also expected to increase the total grant amount of the INPP faculty.

We wish to emphasize that the grant amount of the INPP faculty is such that they feel the pressure exerted by the very lean administrative staff in the Department of Physics and Astronomy. Faculty in the INPP and the department are sorely in need of help with grant preparation, grant administration and budgeting. An increase in grant amount will clearly increase the need for additional staff.

Since the income of the INPP results from the overhead return of grant expenditure, the income lags essentially 6-10 months behind the grant awards. The average income over the past 5 years was roughly \$100,000 per year. From this, the INPP can assist in the support of 2 postdoctoral researchers at a level of \$20K per year, which is a good way to leverage bigger grants from external funding agencies. The INPP supports a vigorous seminar and visitor program at a cost of about \$10K per year. This expenditure is expected to increase. The INPP also contributed to the startup of two new faculty, and carries commitments related with renovations in the Edwards Accelerator Laboratory within the URP program "Structure of the Universe" in the amount of \$10K per year for the next 3 years (5 years in total). About \$6K were used to co-sponsor conferences as quoted in Section 3.3. The INPP traditionally matches Research Challenge Awards of the INPP faculty, and gives partial support for stipends for undergraduate students. In future, the INPP plans to use some of its funds to launch the extension of the graduate program in the Department of Physics and Astronomy to include M.S. and Ph.D. degrees based on research in applied nuclear physics. This support may include partial support of graduate stipends as well as recruiting efforts.

## A Current INPP Graduate Students

<b>Name</b>	<b>Adviser</b>	<b>Research Topic</b>
Aderemi Adekola	Brune	The $^{18}\text{F}(\text{d},\text{n})^{19}\text{Ne}$ Reaction
Zachary Heinen	Brune	The $^9\text{Be}(\alpha,\text{n})$ Reaction
Serdar Kizilgul	Hicks	Double-Polarization Observables for $\pi$ Photoproduction
Ting Lin	Elster	Relativistic Three-Body Problem
Moses Oginni	Grimes	Study of Level Densities for Nuclei with $50 \leq A \leq 85$
Paul Petersen	Brune	Experiment on Neutron Scattering off Iron
Sergey Postnikov	Prakash	Thermal and Transport Properties of Neutron Star Matter
Daniel Sayre	Brune	The $^{11}\text{B}(\alpha,\text{n})$ Reaction
Shaleen Shukla	Grimes	Calculation of Level Densities near the Drip Lines
Anton Wiranata	Prakash	Topics in Relativistic Heavy-Ion Collisions
Chieh Jen Yang	Phillips	Effective Field Theory for Few-Nucleons

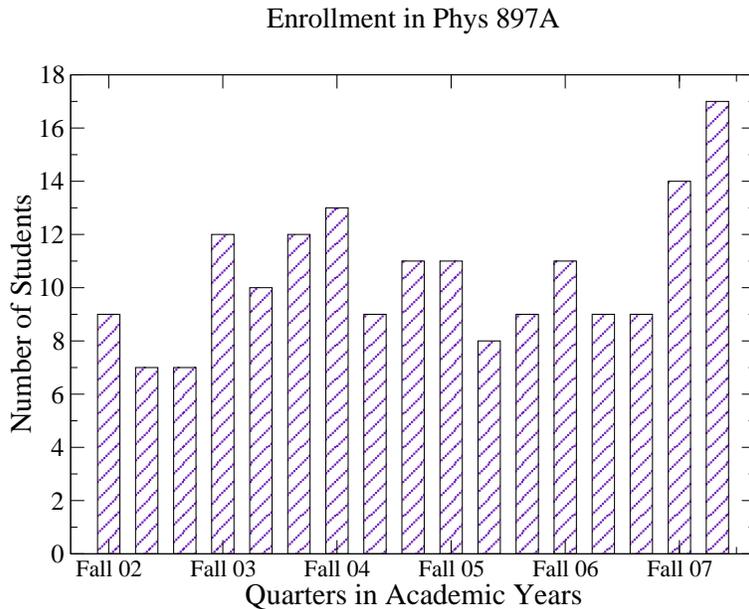
## Current Undergraduate Research Participation

<b>Name</b>	<b>Adviser</b>	<b>Research Topic</b>
Andrew Dilullo	Grimes	Improved Techniques for Detector Calibration
Katie Kinsley	Roche	Characterization of the quartz detector for QWEAK
Colin McGrone	Prakash	Fluctuations in Quantum Gases
Patrick Greeve	Prakash	Quarks in Neutron Stars

## Enrollment in Phys 897A

As mentioned in Section 4, the INPP faculty will continue to hold the weekly student nuclear lunch seminars in order to introduce and discuss a variety of current research topics in nuclear/particle physics and astrophysics. An important objective fulfilled by these seminars is that they enable communication between students performing diverse research in experimental and theoretical physics. As students in experimental physics have their offices in the Edwards Accelerator Laboratory and those in theoretical physics are located in Clippinger Labs, interaction between these students is not as natural as it would be were they to be housed in the same building. In addition to the more advanced students (assisted by faculty) who lead the discussion, the seminars are attended by many interested first year students.

In adding the student component to our regular seminar, the INPP faculty deemed it necessary for students get a broader education in current topics than can be provided by the regular course sequence PHYS 726, 727, and 728, which covers the basics in nuclear and particle physics. The seminars are conducted with sufficient flexibility for students to absorb advances made and to partake of the excitement in the field. In a given quarter, themes are generally linked to topics covered by colloquium or seminar speakers so that students can better appreciate the presentations. This seminar series thus constitutes a course in frontier topics in nuclear/particle physics and astrophysics. The growth in the enrollment for PHYS 897A in recent years is unmistakable (Fig. 2) and propels the INPP to achieve higher numbers in the future.



**Fig.2:** Enrollment in Phys 897A since its inception in the Fall Quarter of 2002.

## B INPP Graduates – 2001-2006

Name	Ph.D.	Adviser	Current Position
Christopher Bade	2006	Hicks	Instructor for Nuclear Physics, US Navy
Deepshikha Choudhury	2006	Phillips	Postdoc GWU
Ishaq Hleiqawi	2006	Hicks	Computer Programmer
Catalin Matai	2006	Brune	Postdoc ORNL
Hang Lui	2005	Elster	Postdoc MSU
Yannis Parpottas	2005	Grimes	Postdoc in Cyprus
George Caia	2004	Wright	Postdoc, Medical Physics OSU
Glen MacLachlan	2004	Opper	Postdoc, New Mexico State U
Americo Salas	2004	Grimes	Postdoc, LANL
Ashghar Kayani	2003	Ingram	Postdoc, Montana State U
Eugene Trifan	2003	Ingram	
Khamit Ardashev	2002	Hicks	Postdoc, U. Virginia
Yixiu Kang	2002	Ingram	Research Scientist, Anderson Cancer Center
Jim Oldendick	2002	Grimes	Pursues Advanced Degree in Math, U.WV
Raymond Wheeler	2002	Grimes	Software Developer
Diane Reitzner	2002	Opper	Postdoc U Guelph, CA
Spring Wang	2001	Rapaport	Medical Physics
Mathew Carmel*	2005	Prakash	Finance (Boston)
Sasa Ratkovic*	2005	Prakash	Finance (London)
Andrew Steiner*	2002	Prakash	Postdoc MSU

\* Those students were advised by Prof. M. Prakash and graduated from Stony Brook University.

### Master Degrees – 2000-2006

Name	Degree	Advisor	Current Position
Hayrullo Shoniyozov	2005	Phillips	
Damodar Pohkrel	2004	Grimes	
John Bevington	2004	Brune	Graduate Student Washington State U
Yuri Pidophryhora	2003	Phillips	Ph.D. in Astrophysics
Gary Steinberg	2003	Onley	
Adam Weisberg	2002	Hicks	

Dirk Blankenberg	2001	Onley
Shahid Qamar	2000	Ingram
Rakesh G Krishna	2000	Ingram

### Undergraduate Research Participation – 2001-2006

Name		Advisor	Current Position
Ryan Zavislak	2006	Hicks	Math Division, NSA
Colin McCrone	2006	Prakash	Undergraduate at OU
Patrick Greene	2006	Prakash	Undergraduate at OU
Daniel Sayre	2005-06	Carman	Graduate Student, OU
Christopher Dodson	2003-05	Brune	

### Selected Previous INPP Graduates

<b>Name</b>		<b>Ph.D. Advisor</b>	<b>Current Position</b>
Chen-Hu Chang	2000	Wright	Software Engineer (Bradley Corp.)
Po-Lin Huang	1999	Grimes	College Teaching (Taiwan)
Cheri Hautala	1999	Rapaport	Science Specialist (Washington DC)
Steven Weppner	1997	Elster	Associate Professor, Eckard College, FL
Saleh Al-Quraishi	1997	Grimes	Associate Professor, Saudi Arabia
Kyungsik Kim	1996	Wright	Assistant Professor (Korea)
Rodney Michael	1995	Hicks	Associate Professor (Ashland, OH)
Hong Zhang	1995	Hicks	Computer Programmer
Fred Bateman	1994	Grimes	Staff Scientist NIST
Jim Guillemetter	1994	Grimes	High School Teacher, Maine
Anita Kumar	1994	Onley	Computer Programmer
Xun Yang	1994	Rapaport	Sen. Systems Engineer Motorola
Werner Abfaltrer	1994	Finlay	Staff Scientist LANL
Lian Wang	1993	Rapaport	Computer Programmer
Henry Clark	1993	Hicks	Accelerator Physicist, Texas A&M
Frank Lee	1993	Wright	Associate Professor, GWU

## C INPP Postdoctoral Researchers

<b>Name</b>	<b>INPP</b>	<b>Area</b>	<b>Current Position</b>
Prashant Jaikumar	2006-	N Theory	
Tsutomu Mibe	2004-	ME Exp	
Lucas Platter	2005-	N Theory	
Alexander Voinov	2005-	LE Exp	
Simon Taylor	2004-06	ME Exp	Postdoc TJNAF
Anders Gardestig	2003-05	N Theory	Postdoc, U. South Carolina
Michael Hornish	2003-06	LE Exp	Bechtel Nevada, DOE SubContractor
Yong Liang	2003-05	ME Exp	Position in China
John Mahon	2002-06	ME Exp	Postdoc BNL
Vladimir Pascalutsa	2001-03	N Theory	5-year Fellow, ECT*, Italy
Avto Tkabladze	2000-04	ME Exp	Postdoc GWU

## D Visiting Scientists

Interactions with scientists visiting for a few days up to a few weeks are not only important for collaborations with the INPP faculty, but also allow the students to interact with scientists outside of Ohio University on a person-to-person basis. In addition, these visits allow scientists to get to know the INPP and Ohio University and to spread the word about us. For this reason, the INPP helps to support collaboration visits financially.

During the last five years, INPP supported the extended visits of:

- Magne Guttormsen, Sunniva Siem, Ann-Cecilie Larsen, Naeem Ul-Hasan Syed, U. Oslo (Fall 2006)
- Andreas Schiller, MSU (Fall 2006)
- Wanpeng Tan, U. Notre Dame (Fall 2006)
- Alan Carlson, NIST (Fall 2006)
- S.I. Dutta, SUNY Stony Brook (Fall 2006)
- Mathew Carmel, SUNY Stony Brook (Fall 2006)
- Frank Dietrich, LLNL (Fall 2005)
- Wayne Polyzou, U. Iowa (Spring 2005)
- Walter Glöckle, Ruhr-University Bochum (Fall 2005)
- Harald Griebhammer, TU Munich (Fall 2004)
- Hadi Hadizadeh, U. Teheran (Fall 2003 - Spring 2007)
- A. Sibirtsev, Forschungszentrum Jülich (Winter 2003)
- John A. Tjon, U. Utrecht, (Spring 2003)
- A.V. Shebeko, Kharkov Institute for Physics, Ukraine (Summer 2003)
- O. Scholten, U. Amsterdam (Spring 2003)
- K. Kim, Korea (Summer 2003)
- I. Fachruddin, U. Bochum (Fall 2002)

## E Research Highlights

The research activities of the INPP fall into two broad categories: (1) Experimental Nuclear/Particle Physics and (2) Theoretical Nuclear/Particle Physics and Astrophysics. At Ohio University, these two activities are carried out with mutual collaboration whenever possible. As great advances are generally made by intense discussions, the INPP strives for synergy between theorists and experimentalists so as to spur creativity in both classes. The description that follows emphasizes this fortunate and unbreakable connection in the physics world.

### Experimental Nuclear and Particle Physics

In experimental investigations, the INPP faculty cover a broad range of topics. In medium-energy experiments, the structure of protons and neutrons (nucleons) are probed to reveal how their constituents, quarks and gluons, interact. The smaller the structure to be investigated (the proton's size is about  $10^{-13}$  cm), the higher the energy of the projectile used to probe the structure. In low-energy experiments, the structure of nuclei (of radius several times  $10^{-13}$  cm) and the relevant reaction cross sections crucial for nuclear astrophysics are investigated.

### Medium-Energy Regime

The intricacies of a proton's substructure is immensely interesting as experiments (in which the INPP faculty have been major contributors) have revealed that there is a flurry of activity inside the proton. Three quarks, two up and one down, primarily account for the proton's charge and baryon number. However, the proton's spin, mass and magnetism remain a mystery. Gluons, that mediate interactions between quark-quark and quark-antiquark pairs of all varieties, hold the key to a satisfactory explanation. This is because the proton is constantly filled with quark / antiquark pairs of not only the light up and down variety, but also by the significantly more massive strange quark / antiquark pair. The fundamental question is: compared to the up and down quark / antiquark pairs how much does the strange quark / antiquark pair, pried out of the sea of filled quarks of all known types, contribute to the proton's spin, mass and magnetism. A quantitative experimental answer to this question including the case of the neutron has far reaching consequences extending to the interior structure a 10 km neutron star that may contain a kaon (made of anti-up and strange quark) condensate.

The **G0 collaboration**, in which the INPP faculty participate actively, investigates the above fundamental issues. Profs. **Julie Roche** and **Paul King**, who joined the OU faculty in Fall 2006, are experts in determining the distributions of charge and magneti-

zation in the nucleon. They are perfectly poised to find out whether these distributions have any contribution from strange quarks as they exist only "virtually" in nucleons due to the quantum mechanical interplay between mass and energy. First results from the G0 experiment carried out at the Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News, VA, were presented in 2005. These results unraveled a detailed picture of the strange quark sea (Phys. Rev. Lett. 95, 092001 (2005)). The experiment consisted of scattering highly energetic polarized electrons off protons within a hydrogen target. The data suggest that strange quarks contribute about 5% of the proton's magnetic moment. These first experiments will be followed up with additional measurements, in which Profs. Roche and King are actively involved. For a non-technical account, see the attached featured article from a 2006 CERN Courier entitled *Investigating the Proton's Strange Sea*.

Manifestations of strange quark contributions were also studied in a very different context, namely in a measurement of the transfer of spin from electrons to strangeness-bearing Lambda-hyperons. Spin is an intrinsic quantum-mechanical property of all subatomic particles, and a particle's spin can be polarized using strong electric and magnetic fields. The Lambda particle contains a strange quark, and its structure is such that the strange quark carries most of the spin of the Lambda. When the Lambda is created from a collision of a high-energy electron and a proton, the result is that the Lambda gets polarized in the direction of the electron's spin. This result was unexpected, as some theoretical models predicted that the spin transfer would be nearly zero. These measurements were carried out by Profs. **Daniel Carman** and **Ken Hicks** (as spokespersons) in the CLAS collaboration at TJNAF. An article from a 2003 Cern Courier *Jlab Results put new spin on the vacuum* is included.

During the last five years, the topic of **charge symmetry breaking** made considerable progress with attendant headlines. In the 1930's, Nobel laureate Werner Heisenberg proposed that the neutron and proton are slightly different manifestations of the same particle, the "*nucleon*". Modern nuclear physics endorses this view; many nuclear reactions proceed similarly if a proton takes the place of a neutron and vice versa. However, this close similarity breaks down in some cases leading to a phenomenon called **charge symmetry breaking** (CSB). In separate experiments at the TRIUMF cyclotron and the Indiana University Cyclotron Facility (IUCF), researchers have made ground-breaking new measurements of CSB. Such CSB measurements can provide insight into why the neutron and proton possess slightly different masses. On a more fundamental level, a precise value for the mass difference between the up and down quarks can be extracted. Prof. **Allena Opper** was one of the spokespersons of the TRIUMF experiment, in which CSB was detected in a reaction in which protons and neutrons fuse, and a charged pion is produced. Viewed from a reference frame in which the proton and neutron meet at the center, this reaction produces a very small excess of pions (0.17%) in a preferred direction. Such an asymmetry is a signature of CSB. In the nuclear theory group, postdoctoral

theorist **Anders Gardestig** calculated a part of the reaction measured at IUCF and subsequently collaborated with Profs. **Daniel Phillips** and **Charlotte Elster** to perform calculations of pion production in reactions of neutrons and protons. As a result, three articles in Science News *Rare Events: Exotic Processes probe the Heart of Matter*, Physics Web *Big Break for Charge Symmetry*, and Cern Courier *TRIUMF and IUCF provide new results on CSB* were published and are included.

Another topic that received wide media attention was the report that a new type of particle, the **pentaquark**, was discovered. The existence of a pentaquark state, made up of 4 quarks and one antiquark, was predicted earlier in theoretical models. Experiments initially showed indications of its existence at the mass predicted for the pentaquark, both in the data from the SPring-8 Facility in Japan (led by **Nakano** and **Hicks**) and those from TJNAF (led by **Ken Hicks** and **Daniel Carman**). Positive evidence was also reported at ten other research laboratories around the world. This produced a sensation in the news media, culminating with Discover Magazine placing it in the top ten of all science results of 2003. But data with higher statistics from TJNAF (again led by **Hicks** and **Carman**) in 2005 showed that the earlier result stemmed from statistical fluctuations. In contrast, higher-statistics data from SPring-8 showed a stronger pentaquark signal. This controversy is not settled, and still captures the attention of the physics community. Several papers on this topic were published in Physical Review Letters. The original announcement has received over 500 citations. Articles from the Symmetry Magazine, the New Scientist, a TJNAF news release and Physics News Update are included.

The Standard Model including the unification of electro-weak physics has been confirmed with remarkable precision in a variety of experiments. In recent years, the physics community is enthralled by the neutrino data from Super-Kamiokande, SNO and the “g-2” experiment, all of which suggest positive evidence for physics beyond the Standard Model. Given the maturity of the Standard Model and the solid data on which it is based, measuring and understanding physics that is not yet understood will require high precision measurements in carefully selected kinematic regimes. Such an experiment is one of the flagship experiments at TJNAF. This QWEAK experiment is a precision measurement of parity violating asymmetry in  $ep$  elastic scattering at low momentum transfer in order to measure the weak charge of the proton,  $Q_W(p)$ . Profs. **Julie Roche** and **Paul King** are members of the QWEAK collaboration, as is **Allena Opper**, now at George Washington University. This experiment, which was proposed in 2001, plans to start taking data in 2009. Data are expected to be sensitive to several different extensions of the Standard Model, allowing tests of new physics. Complementary experiments in the future include those at the Large Hadron Collider.

## Low-energy Regime

In many hot and dense astrophysical environments, such as type I supernovae, it is necessary to understand nuclear processes involving radioactive isotopes. Fortunately, it is possible to study these nuclear reactions in the laboratory using radioactive beams. Prof. **Carl Brune** utilizes the  $^{17}\text{F}$  and  $^{18}\text{F}$  beams of the HRIBF facility at Oak Ridge National Laboratory to measure cross sections of proton induced reactions on these isotopes. The reaction  $^{18}\text{F}(p,\alpha)^{15}\text{O}$  in the temperature range of  $(1-4)\cdot 10^8$  K plays an important role in classical novae as its rate significantly affects the production of heavy elements. At TRIUMF, **Carl Brune** and graduate student **Catalin Matei** successfully studied the fusion rate between  $^{12}\text{C}$  and  $^4\text{He}$ , which controls the abundance of carbon and oxygen in the Universe today. Understanding the detectable abundance of elements in the Universe is an outstanding problem in modern science that physicists, chemists, geologists and astrophysicists are all striving to solve. A write-up in the *News from HRIBF* on this series of experiments is appended.

Quantum Electrodynamics (QED), the theory of the atomic world, can accurately specify energy levels with very small uncertainties (in parts per trillion) as the strength of interaction is relatively small (of order 1/100). The knowledge of energy levels in the nuclear realm is not nearly as detailed as it is for atoms. The challenge for quantum chromodynamics (QCD), the theory of the strong interaction, is to make similarly accurate predictions of energy levels of nuclei. Currently, in QCD based models, which have to grapple with a much stronger interaction (strength of order 1-10), accuracies are only as good as 10%. When a nucleus like iron is “heated” by particle absorption to a temperature of about 1 MeV, thousands of energy levels can be populated. Researchers from Norway, Hungary, Russia, Turkey and the US, including postdoctoral researcher **Alexander Voinov** from Ohio University and **Andreas Schiller** from MSU, who is starting at OU in September 2007, found that hot iron nuclei emit more low-energy radiation the lower their energy becomes. This surprising phenomenon led to the News Bulletin *Iron Nuclei, redder than thought?* which is appended.

The low-energy group has also made great strides in the spectroscopy of light neutron-rich nuclei such as  $^9\text{Li}$ ,  $^{10}\text{Li}$ ,  $^{11}\text{Li}$ ,  $^9\text{He}$  and  $^{10}\text{He}$ , which are studied by **Steve Grimes** and **Tom Massey**. The neutron excess over protons in these nuclei is abnormally large. These excess neutrons form a “halo” around the nucleus. The spectroscopy of energy levels of “halo-nuclei” is of great interest as knowledge from this area can be used to shed light on very low density neutron-star matter. Additionally, these nuclei present a major challenge to the received wisdom of the so-far successful Nuclear Shell Model which is likely looking at drastic revisions.

## Theoretical Nuclear/Particle Physics and Astrophysics

In the past five years, Profs. **Elster**, **Phillips**, and **Wright** have made significant contributions to our understanding of the forces that act between, and within, protons and neutrons. **Wright** and **Phillips** have performed investigations of the substructure of the proton. This substructure is now understood in terms of quarks that reside within the proton. **Wright**, working with post-doctoral researcher **Pascalutsa** and graduate student **Caia**, developed one of the most successful models for the scattering of electrons from the proton, and the production thereby of proton excited states. By comparing their model predictions with data taken at the Thomas Jefferson National Accelerator Facility (TJNAF) in a collaboration including **Hicks** and **Carman**, **Wright** and collaborators were able to learn valuable lessons about the way quarks behave inside the proton.

The excited states of the proton (or neutron) lead to the emission of bosons, the lightest being the pion. Prof. **Elster** and collaborators from the Forschungszentrum Jülich investigated the production of the eta-meson in photon collisions with protons and deuterons to better understand the forces between the eta-meson and a proton or a neutron. These forces are not well determined, but are believed to be strong enough to create a nucleus in which an eta-meson is bound for a short time. This research led to a series of publications interpreting measurements carried out at the Mainz Microtron Facility MAMI. The scattering of photons from the proton at low energy can shed light on the interaction between neutrons, which do not form a bound system.

Complementary lessons were learned from studying the scattering of photons from the proton the deuteron (the bound state of a proton and neutron). **Phillips** and collaborators from four other institutions completed a first model-independent analysis of the world's low-energy data on this reaction. Their results place significant constraints on models of proton's structure. Obtaining analogous results for the neutron is a challenge, because neutrons cannot be used directly as a target due to their 14 minute half life. However, information on neutron structure can be inferred from the scattering of photons from the deuterium nucleus. **Phillips** has been actively involved in theoretical calculations which motivate such experiments at facilities in Lund, Sweden and Duke University in Durham, NC. Furthermore, he has worked with graduate student **Deepshikha Choudhury** to perform the first calculations of elastic scattering of photon from a Helium-3 nucleus (which contains two neutrons and one proton). Their results show that novel experiments on this process at the Duke facility can be used to obtain new information on the neutron's substructure.

The substructure of nucleons also manifests itself through the forces between neutrons and protons inside a nucleus. Just as the forces that bind atoms into molecules are residual effects of the Coulomb attraction between protons and electrons in an atom, the nuclear force is a long-distance manifestation of the forces that bind quarks inside the proton. **Elster** has made great advances in nuclear-force descriptions with her work on

the scattering of a beam of protons from a proton target at beam energies which are equal to, or greater than, the proton rest mass. At such energies, effects of Einstein's theory of special relativity must be taken into account. **Elster** is a world leader in calculations that incorporate the requirements of relativity into computations involving the scattering of protons from a deuterium target. In these experiments, detailed information about a rich set of reaction products can be obtained so that the nuclear force at higher energies can be pinned down. Many of these experiments are carried out at the COSY ring at the Forschungszentrum, Jülich, where **Elster** maintains strong ties with both theoretical and experimental colleagues.

At low energies, the scattering of neutrons from protons, and protons from protons, is well understood. The scattering of neutrons from neutrons, however, remains mysterious, as direct experiments cannot be performed. Working with post-doctoral researcher **Gardestig, Phillips** has shown how the uncertainty in extracting information on neutron-neutron scattering can be greatly reduced by employing relations based on "chiral symmetry" which is a property QCD, the fundamental theory of quark interactions. **Phillips and Gardestig** showed that chiral symmetry connects experiments performed at the Los Alamos National Laboratory (that indirectly measure low-energy neutron-neutron scattering) to the "proton-proton fusion" reaction that fuels the Sun. These reactions, which take place inside the Sun, occur too slowly at terrestrial temperatures to be measured directly in the laboratory. So measurements of other symmetry-connected processes provide the best possibility to precisely test our current understanding of the Sun's energy generation. Thus, the Los Alamos experiment, while performed with a different goal in mind, may have important implications for stellar astrophysics.

The chiral-symmetry connection that **Gardestig and Phillips** established has additional important ramifications. Measurements such as those performed at Los Alamos can also constrain the three-nucleon force, essential for binding nuclei together. These forces act only between triplets of protons and neutrons and are also at play in the higher-energy experiments **Elster** is modeling in her work.

## Physics and Astrophysics of Compact Objects

In the fall of 2005, Prof. **Madappa Prakash** joined the INPP faculty as full professor. His research interests lie in the areas of nuclear astrophysics and relativistic heavy-ion collisions. Currently, graduate students **Sergey Postnikov** and **Anton Wiranata** are working toward their Ph.D.'s in these fields.

In astrophysics, **Prakash** conducts research on stellar compact objects such as neutron stars and black holes from their birth to old age. Neutron stars are the densest manifestations of massive objects in the universe, having central densities several times greater than those found in atomic nuclei and a million times larger than found in white

dwarfs. They are ideal astrophysical laboratories to test theories of dense matter physics and provide connections among nuclear physics, particle physics and astrophysics. Neutron stars may exhibit conditions and phenomena not observed anywhere else, such as hyperon-dominated matter, deconfined quark matter, superfluidity and superconductivity with critical temperatures near  $10^{10}$  K, opaqueness to neutrinos, and magnetic fields in excess of  $10^{13}$  Gauss.

**Prakash's** investigations have elucidated on how current and proposed observations of neutron stars can lead to an understanding of the state of their interiors and the key unknowns: the typical neutron star radius and the neutron star maximum mass. He has examined observations made not only with photons, ranging from radio waves to X-rays, but also those involving neutrinos and gravity waves. In addition, he has detailed how precision determinations of structural properties would lead to significant restrictions on the poorly understood equation of state near and beyond the equilibrium density of nuclear matter.

After his arrival to Ohio University, **Prakash** and **James Lattimer** of Stony Brook University were invited to write a major article for the **Hans Bethe** Memorial volume to be published in Physics Reports. The benevolent giant **Bethe**, a Nobel laureate in Physics for his contributions concerning the energy production in our Sun, died on Mar 8, 2005. In this article, a theoretical analysis of neutron star structure, including general relativistic limits to mass, compactness, and spin rates has been made. An in-depth assessment has been made of recent observations such as pulsar timing (which leads to mass, spin period, glitch and moment of inertia estimates), optical and X-ray observations of cooling neutron stars (which lead to estimates of core temperatures and ages and inferences about the internal composition), and X-ray observations of accreting and bursting sources (which shed light on both the crustal properties and internal composition). Together with students, **Prakash** and **Lattimer** have predicted in detail neutrino emission from proto-neutron stars and how neutrino observations of a supernova, from both current and planned detectors, might impact our knowledge of the interiors, mass and radii of neutron stars. They have also explored the question of how superstrong magnetic fields could affect the equation of state and neutron star structure. This has been followed by a look at binary mergers involving neutron stars and how the detection of gravity waves could unambiguously distinguish normal neutron stars from self-bound strange quark matter stars.

## **F National/International Activities of INPP Faculty**

In this Appendix, selected activities of the INPP faculty in national/international activities are highlighted. The activities include involvement in organization of conferences or workshops, participation in review panels of Federal Agencies as well as Program Advisory Committees (PAC) at different national facilities.

### **Conference/Workshop Organization**

- Two faculty of INPP were elected as Fellows of the American Physics Society (APS), Charlotte Elster in 2001 and Ken Hicks in 2005. Only about 1% of all members of the APS are Fellows.
- Louis Wright and Daniel Phillips were both chairing the Gordon Conference on Photo-Nuclear Reactions, which is held on a two-year cycle. Wright served as co-chair in 2000 Phillips in 2002. Phillips then served as chair in 2004. INPP was a co-sponsor of the 2002 as well as the 2004 Gordon Conference on Photo-Nuclear Reactions.
- Charlotte Elster was co-organizer and Scientific Secretary of the 2002 International Conference on Quarks and Nuclei, QNP2002, held at the Forschungszentrum Jülich, Germany. INPP was a co-sponsor of QNP2002.
- Together with Cornelius Bennhold of George Washington University Charlotte Elster and Daniel Phillips organized a workshop on ‘Dynamical Approaches to Meson Photo-production’ at Ohio University in May 2003. About 20 international experts attended the conference. INPP was the major sponsor of this workshop (\$5000) with contributions from TJNAF and GWU (\$1000 each) and support from the College of Arts & Sciences.
- Ken Hicks a co-organizer of the Pentaquark 2004 workshop, held at the SPring-8 facility in Hyogo, Japan. INPP sponsored a reception for the 100+ participants of the workshop.
- Daniel Phillips served as Working-Group Convenor and a member of the Program Committee for the “Chiral Dynamics: Theory and Experiment” meeting in Chapel Hill, NC in September 2006.

### **National Advisory Committees**

- Julie Roche serves as member of the Hall C/TJNAF steering committee.

- Steve Grimes is member of the Program Advisory Committee of the Weapons Neutron Research (WNR) Facility at Los Alamos National Laboratory.
- Charlotte Elster serves on the Advisory Committee for the DOE Institute for Nuclear Theory.
- Charlotte Elster was selected to serve on the national Nuclear Science Advisory Committee to DOE and NSF.

### **Review Panels of Federal Agencies**

- In 2002 and 2005 Daniel Phillips served in the panel of the U.S. Department of Energy conducting the 5-year review of TUNL Low Energy Nuclear Laboratory at Duke University.
- In 2003 and 2005 Carl Brune served in the panel of the U.S. Department of Energy conducting the 5-year review of Wright Low Energy Nuclear Laboratory at Yale University. In 2004 Carl Brune served in 2004 on the panel of the U.S. Department of Energy conducting a three-year review of the Texas A&M University Cyclotron Institute.
- In 2005 Charlotte Elster served in the panel of the U.S. Department of Energy conducting the 5-year review of all theory groups at DOE National Laboratories.
- In 2005 Phillips served as Chair of the National Science Foundation Nuclear Theory panel which reviewed applications and provided advice to the agency on funding in Theoretical Nuclear Physics.
- In 2006 Carl Brune served in the panel of the National Science Foundation conducting a five-year review of the Joint Institute for Nuclear Astrophysics (Physics Frontier Center) at Notre Dame University.

### **Activities in Professional Organizations**

- Charlotte Elster serves as Secretary Treasurer of the Few-Body Topical Group (GFB) of the American Physical Society (APS) since 2003.
- Madappa Prakash served for two years on the American Physical Society's Division of Nuclear committee determining the best thesis in Nuclear Physics. This award is given annually by DNP.
- From 2002 to 2005 Daniel Phillips served on the Executive Committee of the Few-Body Topical Group (GFB) of the Physical Society.

- In 2006 Daniel Phillips served on the Nominating Committee of the American Physical Society's Division of Nuclear Physics
- From 2004 to 2006 Carl Brune served on the Program Committee of the American Physical Society's Division of Nuclear Physics.

## G The Edwards Accelerator Laboratory

The primary nuclear physics experimental facility at Ohio University is the 4.5-MV tandem van de Graaff accelerator located in the Edwards Accelerator Laboratory. This machine is equipped with a sputter ion source and a duoplasmatron charge-exchange ion source for the production of proton, deuteron,  $^3\text{He}$ , and heavy ion beams. Pulsing and bunching equipment are capable of achieving 1-ns bursts for proton and deuteron beams, 2.5-ns bursts for  $^3\text{He}$  beams, and 3-ns bursts for  $^7\text{Li}$ . The accelerator belt was replaced most recently in March 2004; the accelerator has performed very well since that time with good stability for terminal voltages up to 4.0 MV.

The Laboratory is very well equipped for neutron time-of-flight experiments. A beam swinger magnet and time-of-flight tunnel allow flight paths ranging from 4 to 30 m. The tunnel is very well shielded, and the swinger-magnet assembly allows angular distributions to be measured with a single flight path. Several types of neutron detectors are available, including lithium glass and NE213. Three intrinsic Ge detectors are available for high-resolution  $\gamma$ -ray studies (two coaxial detectors of 40% and 75% relative efficiency and one 15-mm-thick $\times$ 2000-mm<sup>2</sup>-area planar detector). A scattering chamber is available for Rutherford backscattering measurements and other charged-particle measurements. A time-of-flight spectrometer is also available for charged-particle studies. Finally a new beamline for  $\gamma$ -ray spectroscopy studies has recently been constructed.

The Edwards Accelerator Laboratory building is well supplied with computational resources. Every faculty member, postdoc, and student has a modern PC-based computer system (typically Linux or Windows operating system) on their desk. Many additional computers are available for special purposes (e.g. data acquisition, data analysis). Furthermore we have a “Beowulf class” computer system consisting of 16 dual-CPU and 8 single-CPU microcomputers using the Linux operating system. Thirty-two CPUs are Intel Celeron 400 MHz processors, one is a 755 MHz AMD Athlon processor, one is an Intel 1.4 GHz Pentium processor, and six are AMD Athlon 1.2 GHz processors. Each node also includes at least one 4-GB local disk and an ethernet interface. A total disk space of about 200 GB is shared among all the nodes. This system is particularly useful to the nuclear physics experimentalist for running Monte Carlo simulations.

We have recently completed a new “distributed DAQ” data acquisition system which is made up of 16 single-PC nodes connected to a central computer. Each node consists of an independent computer and Distributed DAQ hardware that is dedicated to a single detector or detector-telescope system. This system is running the Linux version of the Ohio University DAQ software for each detector or detector-telescope. Each computer has a board with two charge-to-time converters (MQT300A) and one multi-hit eight-channel time-to-digital converter (MTD133B) from LeCroy. The charge converter has 3 selectable ranges and an optional variable range. Each charge converter has a maximum dynamic

range of over 500. This system can operate at high data rates, has excellent time stability, and eliminates cross talk between detectors. It is particularly advantageous for neutron time-of-flight experiments.

### **Refurbishment with URP/INPP Funds:**

As part of the URP enhancement of our facilities, \$100K has been allocated over 5 years for upgrading the Edwards Accelerator Laboratory (\$10K / year from the URP and \$10K / year from INPP).

In year one we addressed the gas compressor which is used to transfer sulfur hexafluoride (SF-6) gas to and from a storage tank when the accelerator needs maintenance. The compressor had been leaking considerably - we estimated the cost in lost SF-6 to be \$3K / year. The refurbishment was carried out by the Norwalk Compressor Company at a cost of \$23,457.

In year two we have purchased the following items for accelerator monitoring and control:

- 3 Agilent Multifunction Switches (34980A)
- 2 Agilent 40-channel Multiplexers (34921A)
- 1 Agilent 40-channel Reed Multiplexer (34923A)
- 2 Agilent 4-channel D/A Converters (34951A)
- 6 Agilent terminal blocks

We are currently able to control 8 quadrupole power supplies by computer. We plan have all of the magnet power supplies in the laboratory under computer control in the very near future. In addition we are continuously logging approximately 65 streams of data from various devices in the laboratory (typically currents, voltages, pressures, or temperatures). These data is made available to the accelerator operator in the control room. Data are accumulated weekly, then archived, and a new data set is started. A two-hour graph of the monitored parameters can be viewed online at

*<http://edwards1.phy.ohiou.edu/~carterkde/tandem/tandem.html>*

at any time. This feature allows the accelerator technicians and scientists to monitor machine performance from anywhere with internet access (e.g. from home on the evenings or weekends). The logged parameters are stored forever in a database which can be queried. No purchases of computers, networking hardware, or software have yet been necessary. All software was written for Linux/X-Windows in-house. One particularly

unique aspect of the logging system is the use of wireless networking to deliver data from the 40-kV ion source platform.

In addition we have purchased several resistors for the accelerator column. We will also be purchasing a straddle truck in the very near future. This item can be used as a forklift to move heavy items in the laboratory and can also be used to lift a person so that elevated items (such as ceiling lights) can be accessed. The straddle truck will be very helpful for organizing equipment which is not presently being utilized. We will proceed with this purchase once we receive proper certification from the Ohio University OSHA Coordinator regarding our intended use of this item.

### **Equipment for Machine Shop:**

An Elox Electrical Dishcharge Machine (EDM) was obtained for the Physics and Astronomy Machine Shop. This modern device removes material using an electrical discharge rather than a machine tool. It is particularly useful for machining intricate contours or when minimal tool pressure is required.