The 2015 MoNA Report

The MoNA Collaboration

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At the time of this 2015 MoNA (Modular Neutron Array) Report, our collaboration remains as strong as ever. Since we first began 13 years ago using MoNA for nuclear physics experiments, we have published 40 peer reviewed articles, primarily in Physical Review Letters, Physical Review C, Physics Letters B, Nuclear Physics A, and Nuclear Instruments and Methods A, with over half of them including undergraduate co-authors. Recent scientific highlights of our group’s work include a study of neutron correlations in the decay of excited $^{11}\text{Li}$, selective population of unbound states in $^{10}\text{Li}$, population of $^{13}\text{Be}$ using charge-exchange reactions, characterization of low-lying states in $^{12}\text{Be}$, a search for unbound $^{15}\text{Be}$ states using the $^{12}\text{Be} + 3\text{n}$ channel, three-body correlations in the decay of the $^{26}\text{O}$ ground state, analysis of $^{10}\text{He}$ production mechanism using a $^{14}\text{Be}$ secondary beam and a deuterated target, and a measurement of the low-lying excited states of $^{24}\text{O}$ (which served as the LISA commissioning run). Recently completed experiments under analysis include a study of the equation of state using rare isotope beams, knockout reactions on p-shell nuclei, and in summer 2015 an experiment to measure the ground state energy of $^{10}\text{He}$ using two separate production mechanisms was completed. Approved experiments for the near future include a measurement of the $^{9}\text{He}$ ground state, and lifetime measurements with a decay-in-target method. To date 8 graduate students have completed their PhD degrees in MoNA research, 2 will be completing them soon, and 3 are relatively new to the group. By now 159 undergraduate students have participated in MoNA research, and have presented their research 56 times at national physics conferences. And for the first time our summer working retreat workshop was held outside of the state of Michigan, in sunny Santa Barbara, CA. The main goal of our collaborative effort is the execution of high quality research in nuclear science, with undergraduate participation at the heart of our efforts. This vision will continue to drive our efforts in future years with a shared goal of helping inspire and prepare the next generation of physicists.

Warren Rogers
Executive Director, the MoNA Collaboration
Santa Barbara, CA, July 31, 2015
1 Introduction

The exploration of the limits of stability and the observation of new phenomena in nuclei far from stability has been identified as one of the key science drivers for a next generation U.S. facility for rare-isotopes [1]. The first step following the discovery of new isotopes is the study of fundamental properties, for example, masses, binding energies, and lifetimes.

At the very extreme of neutron-rich nuclei, the nuclei beyond the dripline are very short lived and can only be studied by reconstruction based on information gathered from their decay products. Also, nuclei close to the neutron dripline have no or only a few bound excited states, so that traditional γ-ray spectroscopy cannot be applied. However, these states can be explored by neutron–fragment coincidence measurements. Reactions on such exotic nuclei reveal dynamical nuclear properties such as new preferred modes of excitations. When such reactions involve neutrons they are often of interest for explosive astrophysical scenarios. The most efficient and economical way to produce and perform experiments on these nuclei is with rare isotopes produced by high-energy projectile fragmentation. In order to reconstruct the decay energy spectrum, a magnet to deflect the charged fragments and a highly efficient position sensitive neutron detector are necessary.

The Modular Neutron Array (MoNA) was constructed and is operated by a unique collaboration of primarily undergraduate physics departments in partnership with Michigan State University. It has already involved more than 100 undergraduates from over 25 colleges and universities in nuclear physics experiments. The MoNA collaboration is poised to play an important role in educating the next generation of nuclear physicists. This paper outlines the importance of the physics which MoNA can do at a fast fragmentation facility and the potential role of the collaboration in educating future nuclear physicists.

The publications and presentations that detail the results obtained by the collaboration can be found in Section [3]. Also cataloged are the students that have benefited from work with the device in Section [4]. A summary of the systems studied is shown in Figure [5].

2 Physics with MoNA

2.1 Results and perspectives

Nuclear structure and reactions at and beyond the dripline

Along the neutron dripline where the neutron binding energy becomes zero, the relatively small enhancement of the total binding energy for paired neutrons has an important effect. The stability of nuclei with even numbers of neutrons \(N\) compared to their neighbors with odd numbers creates a saw-tooth pattern in which the heaviest odd-\(N\) isotopes of a given element are neutron-unbound, while heavier isotopes with an even number of neutrons can be bound. Well-known examples are \(^{16}\)Li (bound) and \(^{11}\)Li (bound), or \(^{21}\)C (unbound) and \(^{22}\)C (bound). The properties of the alternating neutron-unbound nuclei provide important insights into the neutron–nucleus interaction far from stability, the coupling to the continuum in neutron-rich systems, and the delicate structure of multinucleon halos or skins. In addition, the wave functions of the even-\(N\) nuclei at the dripline are not well known, and studies of the adjacent neutron-unbound (odd-\(N\)) nuclei can yield single-particle information crucial for the characterization of the heavier bound nuclei.

Properties of neutron-unbound nuclei

Intense fragment beams of the most exotic bound nuclei have been used at the National Superconducting Cyclotron Laboratory (NSCL) and elsewhere to extend mass determinations from reaction \(Q\)-value measurements to neutron-rich nuclei beyond the dripline, where the ground state is an unbound resonance. In a typical experiment, the energies and angles of the neutron and the fragment from the decay of the unbound parent nucleus must be detected with sufficient precision to allow reconstruction of the energies of the resonant states. The observed decay energy determines the mass while the width of the resonance is related to the angular momentum of the state. Just as for traditional transfer reactions, different reaction channels provide complementary information, and both proton and neutron removal reactions are important and necessary to populate the neutron-unbound states. Nuclear masses and angular momenta of ground-state wave functions of unbound nuclei provide information on the shell structure at the neutron dripline that cannot be obtained by other means.

Neutron-unbound excited states

Neutron-unbound excited states of bound nuclei can be populated either in nuclear breakup reactions via excitations from the ground state or via particle removal reactions from neighboring nuclei.

Breakup reactions where the nucleus is excited via the nuclear or Coulomb interaction are versatile tools to study continuum properties. For example, Coulomb-breakup of halo nuclei is mostly sensitive to the \(s\)-wave component of the ground-state wave function and hence will be able to provide a spectroscopic factor for a core \(s\)-wave configuration in the ground state of the nucleus of interest [2]. Such measurements could be precision tests of results from the more common knockout or transfer reactions, since the reaction mechanism of Coulomb breakup is better understood theoretically.

Several interesting quantities are accessible by particle removal reactions. For one, the energy and decay path of resonances are of interest for nuclear structure. Also, high-lying first excited states are indicative of gaps in the single-particle level scheme and suggest new magic numbers. The energy of resonances can shed light on the
When the last neutrons in a nucleus are weakly bound, nuclei have been found to exhibit neutron halos \[5\], and systems \[3, 4\]. Close to the neutron dripline, a number of structures are also found in atomic and molecular systems, different from those of well-bound systems. The study of neutron-unbound systems using the Sweeper and MoNA-LISA devices is based on the well-established technique of invariant mass measurements.

**Neutron halos**

Weakly bound few-body systems have been found to exhibit properties such as halo structures, which are very different from those of well-bound systems. The study of these neutron halos is important for a better understanding of nuclear structure close to the drip-line and also helps to understand the universal features of weakly bound few-body systems in general. For example, halo structures are also found in atomic and molecular systems \[3, 4\]. Close to the neutron dripline, a number of nuclei have been found to exhibit neutron halos \[5\], and many more are predicted to exist \[4\].

When the last neutrons in a nucleus are weakly bound and have predominant s-wave character, the absence of a confining Coulomb and angular-momentum barrier allows the extension of the neutron wave function far beyond the nuclear core via quantum-mechanical tunneling. The attraction of the nuclear potential is weak in this extended region and, as a result, the nucleus develops a diffuse halo with one or a few neutrons distributed over a large volume. The radial wave function of such a halo depends critically on the neutron separation energy. Thus, precise measurements of nuclear masses and separation energies of these exotic systems provide important information for theoretical descriptions as well as for the identification of new halo candidates.

### 2.2 Invariant mass measurements

The study of neutron-unbound systems using the Sweeper and MoNA-LISA devices is based on the well-established technique of invariant mass measurements. Determining the population of unbound states in nuclear reactions through knock-out, breakup, or transfer reactions, followed by detection of all of the decay products in coincidence, i.e., the neutron (or neutrons, indexed \(n\)) and the charged fragment (indexed \(f\)), is necessary. Measurement of the energies \((E_n, E_f)\) and momentum vectors \((\vec{p}_n, \vec{p}_f)\) of the involved particles enables the reconstruction of the invariant mass or the decay energy (see Figure 2). The decay energy \(E_d\) is the invariant mass of the unbound system minus the sum of the separate particles’ masses and for one-neutron decay is given by:

\[
E_d = \sqrt{m_n^2 + m_f^2 + 2E_nE_f - \vec{p}_n \cdot \vec{p}_f} - (m_t + m_n)
\]

These invariant mass measurements are performed with a large-gap dipole magnet or “Sweeper” that separates the unreacted beam, charged reaction products, and neutrons in such a way that the forward-going undeflected neutrons are cleanly detected in a high-efficiency neutron detector such as MoNA-LISA (see Figure 2).

### 2.3 Technical overview

**Modular Neutron Array**

The Modular Neutron Array (MoNA) is a large-area, high-efficiency neutron detector designed for neutrons resulting from breakup reactions of fast fragmentation beams.

In its standard configuration, MoNA has an active area of 2.0 m wide by 1.6 m tall (see Figures 3 and 6). It measures both the position and time of neutron events with multiple-hit capability. The energy of a neutron is based on a time-of-flight measurement. This information together with the detected position of the neutron is used to construct the momentum vector of the neutrons \[6, 7\].

**Figure 1**: A portion of the chart of the nuclides showing collaboration measurements.
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Figure 2: The reconstructed decay-energy spectrum for the neutron-unbound ground state in $^7\text{He}$, which is unbound by 450 keV and which has a width of 160 keV. The data were taken during the commissioning of the Sweeper Magnet and the MoNA neutron detector at NSCL.

Figure 3: The Modular Neutron Array and Large-area multi-Institutional Scintillator Array (MoNA-LISA).

Figure 4: Assembled LISA modules being tested.

The detection efficiency of MoNA is maximized for the high-beam velocities that are available at the NSCL Coupled Cyclotron Facility (CCF). For neutrons ranging from 50 to 250 MeV in energy, it is designed to have an efficiency of up to 70% and expands the possible coincidence experiments with neutrons to measurements which were previously not feasible. The detector is used in combination with the Sweeper magnet [8–12] and its focal plane detectors for charged particles [13]. In addition, the modular nature of MoNA allows it to be transported between experimental vaults and thus to be used in combination with the Sweeper magnet installed at the S800 magnet spectrograph [14]. Due to its high-energy detection efficiency, this detector in conjunction with LISA (see next section) will be well suited for experiments with fast fragmentation beams at FRIB.

Large-area multi-Institution Scintillator Array (LISA)

A collaborative MRI proposal was submitted by nine PUI institutions in the collaboration (CMU, Concordia, Gettysburg, Hope, IUSB, OWU, Rhodes, Wabash, and Westmont) to enhance the neutron detection capabilities. LISA is a second large array (144 modules, see Figure 4) which can be configured for additional angle coverage or for additional efficiency. The increased neutron detection efficiency possible with the combined MoNA-LISA array means it will be an effective day-one FRIB detector system.

LISA was constructed by undergraduate students at the nine institutions (Figure 4). Construction was essentially completed during the summer of 2010. Each institution carried out testing and used their subset of detector modules for student education. The projects being undertaken by students at each institution range from muon-lifetime measurements, to cosmic-ray shower size measurements, to $\gamma$-$\gamma$ correlation measurements using the full position reconstruction. The modules were moved to NSCL in January of 2011. After mechanical installation was completed, LISA was integrated with MoNA and the
The Sweeper magnet is a large-gap dipole magnet that was developed and built at the National High Magnetic Field Laboratory at Florida State University [8–12]. It was funded by the NSF with a Major Research Instrumentation (MRI) grant to a MSU/FSU consortium. The superconducting magnet is able to deflect charged particles up to a rigidity of 4 Tm in order to separate neutrons, charged reaction products, and the non-reacting beam particles. The vertical gap between the pole tips measures 14 cm and a large neutron window enables the neutrons coming from the reaction target placed in front of the Sweeper to reach MoNA and LISA, typically placed at 0° with respect to the incoming beam direction.

Sweeper focal plane box
The Sweeper focal plane box, which is placed at a 43° angle behind the Sweeper magnet, contains the charged particle detectors [13]. A set of position-sensitive cathode readout drift chambers (CRDC) provides position and angle of the charged reaction products. An ionization chamber is used for the energy-loss information and a timing scintillator for the flight-time determination. A segmented CsI hodoscope stops the charged particles at the end of the focal plane box and measures their total kinetic energy. All of these quantities are used to identify the reaction products and to determine their properties such as velocity and direction of movement.

CsI Hodoscope
The CsI Hodoscope was assembled, tested and installed in 2012 by Dr. Nathan Frank and students at Augustana College in Rock Island, IL. The new hodoscope array consists of twenty five sodium-doped CsI crystals (3.25” x 3.25” x 2”) arranged in a 5 x 5 configuration (see [8]). The array measures the kinetic energy of charged fragments with a resolution of approximately 1% for GeV energies. The improved resolution makes experiments utilizing reaction mechanisms such as (d,p) possible.

Segmented Active Target
A segmented target will be available in 2015 for experiments. The target consists of alternating layers of Silicon detectors (62 mm x 62 mm x 140 µ) and Be typical 470 mg/cm², 2,500 µ targets. The energy loss of secondary beam or charged reaction product nuclei are measured in each detector. The energy loss information is used to determine in which target the nuclear reactions take place. This determination will provide a means to keep the resolution in decay energy measurements constant while increasing statistics by making a thicker target.

Liquid Hydrogen Target
The Liquid Hydrogen Target at the NSCL offers a high-density, low-background proton or deuteron target for elastic scattering, nucleon transfer reactions, secondary fragmentation, and charge exchange experiments. The target (see [9]) works by pumping deuterium gas into a cylindrical chamber sealed with ~100 µm thick kapton foils on either side. The target chamber has a diameter of 5cm and can provide several target thicknesses depending on the depth of the chamber and density of the gas. Thicknesses of 200 or 400 mg/cm² are currently available for deuterium. Liquid helium is then used to cryogenically cool the gas close to the triple point, and a heating block warms the deuterium to approximately 1.5K below the boiling point to keep it in a liquid state. The system can hold 160L of deuterium at 1 atm. It was used at NSCL for the 24O(d,p) experiment (e12004) whose goal was to measured negative parity states in neutron-unbound 25O.

Experimental Layouts
The complete experimental setup of MoNA-LISA and the Sweeper magnet is located in a dedicated vault (see Figure 10), in which it is possible to place MoNA and LISA at angles different from 0° with respect to the incoming beam axis. This allows configurations with larger angular coverage, or a measurement of neutrons at large lab angles.

Event-tagged readout
For MoNA-LISA-Sweeper experiments the data from the various detector subsystems are read out in an event-
Figure 6: Schematic layout of the Sweeper–MoNA setup.

Figure 7: The CsI hodoscope with Nathan Frank.
Figure 8: Beam eye-view of the proposed Si-Be segmented target to be used at NSCL.

Figure 9: A diagram of the Liquid Deuterium Target illustrating how it will sit in the beam-pipe.
tagged scheme. Each detector subsystem runs its own readout and records its data separately. By using separate data acquisition computers, the system becomes easily expandable, e.g. if an additional detector subsystem like a $\gamma$-ray detector needs to be added, while the overall readout time is reduced compared to a system with a large number of VME bins. A common system-wide trigger is generated by the trigger logic. A clock signal is fed into scalers that create an event tag for each time the subsystems are read out. This event tag is used off line to match and re-assemble event data from the subsystems.

2.4 Auxiliary uses of MoNA-LISA

In addition to the primary fragmentation physics, there are some off-line uses for MoNA. These include measurements of the temporal and spatial dependence of the cosmic-ray flux. These efforts provide additional student training with acquisition, detectors, and analysis.

3 The MoNA collaboration

3.1 History

When the NSCL upgraded their capabilities to the Coupled Cyclotron Facility, an FSU/MSU consortium built the Sweeper magnet to be used with two existing neutron walls to perform neutron–fragment coincidence experiments. The neutron walls were originally built for lower beam energies and had only a neutron detection efficiency of about 12% for the energies expected from the CCF. During the 2000 NSCL users meeting a working group realized the opportunity to significantly enhance the efficiency with an array of more layers using plastic scintillator detectors.

Several NSCL users from undergraduate schools were present at the working group meeting and they suggested that the modular nature and simple construction would offer great opportunities to involve undergraduate students.

In the spring of 2001 the idea evolved into several MRI proposals submitted by 10 different institutions, most of them undergraduate schools. The proposals were funded by the NSF in the summer of 2001. Following the detailed design, the first modules of the detector array were delivered in the summer of 2002. During the following year all modules were assembled and tested by undergraduate students at their schools [16], and finally added to form the complete array at the NSCL (Figure 11).

The MoNA collaboration continued after the initial phase of construction and commissioning was concluded [17], and is now using the detector array for experiments, giving a large number of undergraduate students from all collaborating schools the opportunity to take part in cutting-edge nuclear physics experiments at one of the world’s leading rare-isotope facilities. The research at the undergraduate institutions is funded by the NSF through several RUI grants (Research at Undergraduate Institutions).

In 2012, Hampton University (which is a Historically Black College), Michigan State University and Augustana College received an award from the National Science and Security Consortium [18], a DoE/NSA funded consortium, to join the MONA collaboration. The HU/MSU/Augustana proposal focused on the construction of the segmented target. Since its involvement, several students from three minority institutions have been included in MONA related research: two graduate students (both from Hampton University) and three under-
The role of undergraduate students

The physical characteristics and performance of MoNA were not the only things carefully considered by the collaboration. From the outset, several goals for the education of undergraduate students were identified: How can these students be continually and effectively involved in forefront research? What are the benefits to the students from this participation? What are the benefits to institutions and faculty members? When students participate in the experiments and when they work with the data sets, how can they evolve from passive watchers to active doers with the responsibility to get answers?

The collaboration has addressed this challenge by creating intensive summer sessions designed for undergraduates, encouraging students to participate in all phases of experiments, holding several meetings a year that include undergraduate participants, and employing information technology to bring the distant undergraduate students together (Figure 12).

Many voices have recognized the need for a strong basic science program in the United States. Most recently the National Academy of Sciences published the “Rising Above the Gathering Storm” study that outlines consequences and needed actions. The coming decade will need a steady stream of people (new physicists) as well as strong financial support. As in the past many of these people will come from undergraduate institutions and the most prepared will be those involved in meaningful undergraduate research as done by the MoNA collaboration at the NSCL involving fragmentation. While planning future installations for nuclear physics, the value of this educational approach and training must be recognized. Undergraduates must be involved in an affirming environment where they are engaged at a high intellectual level and truly challenged so they are ready for the work yet to be done. The MONA Collaboration has now established itself as a powerful collaboration with a strong track record in training undergraduate students to do research and produce peer reviewed articles in nuclear physics.

Outcomes

Since the start of this collaboration, more than 100 undergraduate students from over 25 different colleges and universities as well as a few high school students have been actively involved in building, testing, and operating the MoNA and LISA detectors (see Section 7).

These diverse undergraduate students have worked with one another in assembling and testing MoNA and LISA and in operating it during experiments. They have pulled shifts and put in the long hours that are characteristic of work in experimental nuclear physics. The graduate students and post docs at the NSCL provide approachable
role models for them, and they feel free to ask questions of any of the faculty members in the group. For students from small undergraduate physics departments, participation in the MoNA collaboration provides a chance to experience the way physics is done in a large graduate physics department and at a world-class nuclear physics laboratory. The experience is particularly important for students who do not go on to graduate school in physics because they gain an understanding of how hard experimental scientists work to uncover the data points that underpin the theories written up in science texts and news magazines. The support of physics students who do not work as nuclear physicists but have careers in industry, K-12 education, or even the arts is important in reaching the non-scientists who control the funding for nuclear physics.

Distributed analysis

A feature of the MoNA collaboration that is an outgrowth of our collective work with undergraduate researchers is the emphasis on doing more than detector assembly or running shifts. In particular, the collaboration has a mechanism in place that allows the undergraduates to carry out the actual data analysis of the experiments. One mode is that a student, with guidance from their mentor and the collaboration, has the primary responsibility for the analysis much like a traditional graduate student; other students may be involved but that student does much of the work and oversees and integrates the work of others. Students can work with more senior researchers where they provide hours on task and have a good overview of the experiment but do not have the ultimate responsibility for the results. Undergraduate students with limited time for work can still participate by working on very focused aspects such as the calibration of a single detector subsystem, code checking, or validation of the work of others (Figure 13).

Lastly, some collaboration members have undertaken the difficult task of improving the analysis algorithms and extending the detailed understanding of operations. MoNA undergraduate students at Westmont College have developed an algorithm to distinguish neutron multiplicity based on the kinematic propagation properties of neutrons though MoNA. Initial analysis of several one- and two-neutron experiments show promise. Scatter plots of neutron velocity and energy deposition versus scattering angle reveal a locus of points in which single-neutron events lie. Multiple-neutron events show as relatively uniform scatter throughout the plots, as there is no correlation between each individual neutron interaction in those instances besides the kinematics of the breakup which produced them.

There have not been instances where students wanted to be involved but were not. Undergraduate work has contributed to a number of publications and presentations (see Section 6).

We are able to involve undergraduate students in this way because we have the tradition of expecting such work from our students but also because of the collaboration infrastructure that is in place. Frankly, it would be difficult for single researchers from a primarily undergraduate institution to work successfully with their students on the analysis of such measurements in isolation. The fact that those involved participate in regular video-conferences where recent results and problems can be discussed with others also working on the same experiment or related analyses is crucial. The expertise that comes to the table in this fashion makes the group effort very strong.

Giving the students responsibility for the analysis in these ways additionally results in increased effectiveness during the actual experiments. They are much more involved and make significant contributions by doing preliminary analysis as the data is being recorded.

But the largest benefit to this type of undergraduate involvement is that they are enthused to continue on to graduate study and they are extremely well prepared to continue in research. They have mastered many fundamental research skills and understand the problem solving process that is essential to carry research through to a conclusion. In fact, the MoNA collaboration has dramatically impacted the interest of undergraduate students in pursuing physics graduate school with an emphasis in nuclear physics (Figures 14 and 15).
Figure 14: Career choices of BS/BA graduates from bachelor’s granting institutions in the U.S. from an AIP survey [19] and from the MoNA collaboration. The AIP data is from 1974 respondents from 2011 and 2012, and the MoNA data is based on 97 students from 2002-2014.

Figure 15: Fraction of graduate students in Nuclear Physics. The U.S. fraction corresponds to the average number of PhDs from 2000-2012 [20].

Figure 16: Present job distribution of all current and past MoNA students. 29 students are still in college, 48 students are currently in graduate school, 5 are PostDocs, 62 are employed in STEM fields, 12 are in non-STEM fields, and the status of 7 past students is unknown.

The MoNA collaboration has had a significant national impact regarding the increase of the STEM workforce. The current job and geographic distribution of students are shown in Figures 16 and 17: about 70% of the students go into graduate school or are pursuing a STEM career.

Summer research

Summer is still the best time for undergraduates to get involved in major research projects. In addition to the undergraduate students from the collaborating institutions, many REU students joined the research efforts during the summers. The collaboration used this opportunity for workshops to teach the students about all aspects of MoNA. These workshops include formal presentations and mini-lectures on the experimental details and pertinent background material such as radioactive beam pro-

Figure 17: Geographic distribution of former MoNA students employed in STEM disciplines in the USA. 68 students work in the US and 2 students working in the UK and Malawi.
The MoNA Collaboration

The equipment has allowed undergraduate students to participate in the real-time acquisition and off-line analysis of data. This novel remote approach to doing physics will give students the opportunity to participate in MoNA experiments together with other collaborators from multiple off-site locations and from the NSCL. Students are no longer prevented from participating in an experiment due to academic-year course commitments or travel constraints. The digital video conferencing system also allows faculty and students to have regular group, subgroup and point-to-point meetings where pre-experiment planning is being discussed and post-experimental data analysis is coordinated. The system is further being used for training, educating and motivating students who are new to the project. The system compliments the other forms of communication used by the collaboration, such as databases, websites, phones, and e-mail.

Data analysis and real-time experimental participation, facilitated by the conferencing system, will help students to foster stronger and more confident ties to the MoNA collaboration. This aspect of regular collaborative face-to-face interaction with members of the MoNA collaboration will continue to allow students to be genuine members of the group and contribute to the physics results produced by the collaboration.

Why undergraduate participation works so well with MoNA at NSCL

The MoNA collaboration has found it very easy to involve students in the fragmentation studies at NSCL. The students can readily grasp the basic goals of the measurements. As stated above, the academic atmosphere works well for the faculty and the undergraduate students fit in well (they especially relate to the graduate students), but additionally, the physics is easy for the students to understand. The reconstruction of the original nuclear mass is based on relativistic four-vectors. The nuclear shell model and single particle states, while complex in detail, can easily be related to atomic shells. The students are able to see the big picture while being involved in the experimental detail. Students see moderately complex detector systems but which are actually easily understood. (The concept of determining neutron energy from time-of-flight can be understood by first-year students.) The physics based on fragmentation provides tremendous opportunities for the undergraduate researcher (and their mentors).

In no small measure, the MoNA collaboration has been able to successfully and meaningfully involve undergraduates because the NSCL is an academic setting. The significant interaction of the undergraduate students with the graduate students and senior researchers, that are also instructors, has been very beneficial. The undergraduates are always greatly affirmed and encouraged. The mentors of these students also appreciate the support received from fellow academics.

4 Conclusion

A great deal of cutting edge physics remains to be done utilizing fast fragmentation beams. The evolution of shell closures (magic numbers) as the stabilizing influence of

Figure 18: Participants of the 2012 Beaver Island retreat.
protons in the same orbitals is lost for the most neutron-rich nuclei, which continues to be of particular interest. An additional focus is the study of neutron pairing correlations, which can be studied using neutron-rich nuclei in which sequential two-neutron decay is energetically forbidden, and only direct two-neutron decay can occur. Moreover, reaction studies and cross-section measurements can reveal, e.g., neutron and radiative strength functions. Reactions on exotic nuclei involving neutrons are also often of importance for explosive scenarios in astrophysics.

Many of these neutron-rich nuclei will be accessible at sufficient intensities and at nearly optimal beam velocities as fragmentation beams at a facility like FRIB. The MoNA collaboration has been able to take advantage of the varying areas of expertise of its members to create a collaboration which has effectively involved undergraduate students from its beginning and continues to do so to this day. Students readily understand the nature of these experiments, and can participate in meaningful ways. The impact on these students of exposure to the international-level research currently conducted at NSCL is significant, and helps to train the next generation of physicists. A future isotope research facility that could continue this excellent support of undergraduate research would be welcomed by the MoNA collaboration, and would be an asset for our field of research.

5 Previous Director’s Statements

The MoNA Collaboration consists of a group of researchers, most from primarily undergraduate institutions, who are pursuing studies of nuclei close to and beyond the neutron dripline using the Modular Neutron Array (MoNA). These experiments can only be done with neutron-rich nuclei produced via projectile fragmentation, as carried out, for example, at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University, where MoNA is currently located. Since the first detectors of MoNA arrived for assembly in 2002, 64 undergraduate and high school students (as of Spring 2007) have participated in cutting-edge research in nuclear physics as part of the MoNA Collaboration. These students have assembled and tested the components of MoNA, participated in MoNA experiments and workshops at the NSCL and in the annual collaboration retreat, and played a central role in data analysis. The MoNA collaboration has been a model for involvement of undergraduates in forefront research. The collaboration is committed to continuing its role in the study of nuclei at the limits of stability and in the training of the next generation of nuclear scientists. Our experience over the last six years leads us to the following observations:

• Studies of nuclei at the neutron dripline utilizing beams produced by fast fragmentation produce cutting-edge science. These experiments are well suited to meaningful participation by undergraduate students in a multi-institution collaboration.

• The collaboration has thrived in a university setting, where undergraduate education is at the core of the institutional mission.

We look forward to a next generation facility for rare-isotope beams which would ensure the continuation of this successful scientific and educational collaboration for years to come.

Jerry Hinnefeld  
Executive Director, the MoNA collaboration  
South Bend, January 17, 2007

Since the last version of this document the MoNA Collaboration has continued to thrive and grow. More than 100 undergraduate students have now been part of the collaboration’s scientific endeavors playing vital roles in the study of the nuclei at the limits of stability. Our collaboration has grown in other ways as well. New institutions and investigators have joined the collaboration. Sharon L. Stephenson (Gettysburg College), Nathan Frank (Augustana College in Rock Island, IL), Artemis Spyrou (Michigan State University), Robert A. Kaye (Ohio Wesleyan University) and Deseree Meyer Brittingham (Rhodes College) are bringing new skills and insights to the collaboration’s work. In addition a new detector system is under construction by undergraduates at the collaboration schools. LISA, the Large multi-Institution Scintillator Array, will work in conjunction with MoNA to increase our ability to measure angular distributions of reaction neutrons as well as improve the resolution and efficiency of detection in our experiments.

The MoNA Collaboration has always been forward-looking whether in the preparation of the next generation of physicists or in the construction of detectors that are ready for use in the next generation of rare isotope beam facilities (FRIB). Today, we see a bright future for the collaboration, the NSCL, and rare-isotope physics.

Bryan A. Luther  
Executive Director of the MoNA Collaboration  
Moorhead, MN, Sept. 9, 2010

In the last two years, the MoNA Collaboration has completed LISA, the Large multi-Institutional Scintillator Array. Twenty-three undergraduates worked on construction, testing, and installation of LISA, with additional students playing key roles in data analysis. A successful commissioning experiment in June 2011 continues
our scientific program of probing nuclei at the limits of stability. The higher efficiency and better resolution of MoNA LISA combined will allow the collaboration to study a wide array of isotopes that will be available when the Facility for Rare Ion Beams (FRIB) comes online. Extensive, meaningful undergraduate involvement in the cutting-edge science provides pivotal research experiences for students and contributes to training the next generation of nuclear scientists. The collaboration continues to exemplify a successful partnership between primarily undergraduate institutions and a large research university. We are excited about future research and educational opportunities that will be possible with FRIB and as our collaboration continues to grow.

Deseree Meyer Brittingham  
*Executive Director, the MoNA Collaboration*  
Beaver Island, MI, August 20, 2011

The MoNA Collaboration has continued to demonstrate growth in its scientific and educational objectives and outcomes since the production of the last White Paper. Since the beginning of 2012, 15 papers in refereed journals were published collectively by the collaboration, including cutting-edge studies of the ground-state dineutron decay of 16Be and two-neutron radioactivity in the decay of 26O. A hodoscope particle detector array, intended to increase the sensitivity of the identification of charged fragments, was developed by Augustana College and was implemented in a commissioning experiment at the NSCL last summer. Paul Gueye (Hampton University) has joined the collaboration and is involved in an effort to develop a segmented target, which will determine the location of nuclear reactions within the reaction target and thus provide better resolution in decay energy measurements. Additionally, our mission to help educate the next generation of scientists remains an important cornerstone of our work. Two NSCL graduate students received their Ph.D. in MoNA-related research and over 20 undergraduates from across the participating institutions of the collaboration were involved in research projects in 2012–2013. We also continue to keep a keen eye to the future, making preparations for our experimental program to be a possible “Day One” user of the new Facility for Rare Isotope Beams (FRIB), currently slated for completion in 2022.

Robert Kaye  
*Executive Director, the MoNA Collaboration*  
Beaver Island, MI, August 17, 2013

The MoNA (Modular Neutron Array) Collaboration continued to find success over the past year. To date, we have 37 peer reviewed papers with over half of those having undergraduate students as co-authors. In 2014 three graduate students completed their PhDs and another has data in hand to study the energy gap between the sd Úpf neutron shells in 25O. This year the total number of MoNA Collaboration undergraduate students has surpassed our lucky number of 144—the number of neutron detectors in MoNA or LISA. Our 147 undergraduate students have presented over fifty times at national physics conferences. The infrastructure of the MoNA Collaboration and the tradition of expecting quality work from our students at all levels of their academic careers has led to our improving research opportunities and preparing the next generation of physicists.

Sharon Stephenson  
*Executive Director, the MoNA Collaboration*  
East Lansing, MI July 20, 2014
6 Presentations, publications, experiments, grants

Invited talks

1. The Modular Neutron Array at the NSCL
   T. Baumann for the MoNA Collaboration
   CAARI 2002: 17th International Conference on the Application of Accelerators in Research and Industry,
   CAARI, Denton TX, November 12–16, 2002

2. The MoNA project: doing big science projects with small-college undergraduates
   B. Luther

3. Explorations of the driplines and first results from MoNA
   M. Thoennessen
   International Conference on Frontiers In Nuclear Structure, Astrophysics, and Reactions (FINUSTAR), Kos,
   Greece, September 12–17, 2005

4. Studies of neutron-rich nuclei with the MoNA/Sweeper system at the NSCL
   P. A. DeYoung

5. First excited state of doubly-magic $^{24}$O
   A. Schiller, N. Frank, T. Baumann, J. Brown, P. DeYoung, J. Hinnefeld, R. Howes, J.-L. Lecouey, B. Luther, W. A. Peters, and M. Thoennessen

6. Unbound states of neutron-rich oxygen isotopes
   M. Thoennessen, T. Baumann, D. Bazin, J. Brown, P. A. DeYoung, J. E. Finck, N. Frank, A. Gade, J. Hinnefeld, C. R. Hoffman, R. Howes,
   J.-L. Lecouey, B. Luther, W. A. Peters, W. F. Rogers, H. Scheit, A. Schiller, S. L. Tabor, MoNA Collaboration

7. Unbound states of neutron-rich oxygen isotopes: Investigation into the N = 16 shell gap
   C. R. Hoffman, T. Baumann, D. Bazin, J. Brown, P. A. DeYoung, J. E. Finck, N. Frank, A. Gade, J. Hinnefeld, R. Howes, B. Luther,
   W. A. Peters, W. F. Rogers, H. Scheit, A. Schiller, S. L. Tabor, M. Thoennessen, MoNA Collaboration
   International Nuclear Physics Conference, INPC 2007, Tokyo, Japan, June 3–8, 2007; Program Book, F5-1, p. 14
   (2007)

8. Unbound states of neutron-rich oxygen isotopes
   M. Thoennessen, T. Baumann, D. Bazin, J. Brown, P. A. DeYoung, J. E. Finck, N. Frank, A. Gade, J. Hinnefeld, C. R. Hoffman, R. Howes,
   J.-L. Lecouey, B. Luther, W. A. Peters, W. F. Rogers, H. Scheit, A. Schiller, S. L. Tabor, MoNA Collaboration
   International Conference on Proton Emitting Nuclei and Related Topics, PROCON07, Lisbon, Portugal, June

9. Unbound states of neutron-rich oxygen isotopes
   C. Hoffman
   JUSTIPEN-EFES workshop on shell structure of exotic nuclei 4th workshop by the DOE project JUSTIPEN and
   the JSPS core-to-core project EFES, RIKEN, Tokyo, Japan, June 23, 2007

10. Unbound states of neutron-rich oxygen isotopes: Investigation into the N = 16 shell gap
    C. R. Hoffman, T. Baumann, D. Bazin, J. Brown, P. A. DeYoung, J. E. Finck, N. Frank, A. Gade, J. Hinnefeld, R. Howes, B. Luther,
    W. A. Peters, W. F. Rogers, H. Scheit, A. Schiller, S. L. Tabor, M. Thoennessen, MoNA Collaboration
    International Conference on Nuclear Structure: Nuclear Structure: New Pictures in the Extended Isospin Space,
    Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto, Japan, June 11–14, 2007; Book of Abstracts,
    p. 43 (2007)

11. Unbound states of neutron-rich oxygen isotopes: Investigation into the N = 16 shell gap
    C. Hoffman
    Direct Reactions with Exotic Beams, RIKEN, Tokyo, Japan, May 30–June 2, 2007
12. Proton knock-out reactions to neutron unbound states
   M. Thoennessen

13. Investigating the \( N = 16 \) shell closure at the oxygen drip line
   C. Hoffman

14. Neutron-decay spectroscopy of neutron-rich oxygen isotopes
   5\textsuperscript{th} International Conference ENAM08 on Exotic Nuclei and Atomic Masses, Ryn, Poland September 7–13, 2008; Abstracts, p. 30 (2008)

15. Spectroscopy of unbound states at the oxygen dripline
   C. Hoffman
   Unbound Nuclei Workshop, INFN, Pisa, Italy, November 3–5, 2008

16. Big physics and small colleges: The mongol horde model of undergraduate research
   B. Luther

17. Exploration of the neutron dripline at the NSCL
   M. Thoennessen
   Annual NuSTAR Meeting, March 23–27, 2009, GSI, Darmstadt, Germany

18. Explorations of the driplines
   M. Thoennessen
   Step Forward to FRIB, RIA/FRIB Workshop, May 30–31, 2009, Argonne, IL

19. Shell evolution at the oxygen drip line
   C. Hoffman
   VIII Latin American Symposium on Nuclear Physics and Applications, Universidad de Chile, Santiago, Chile, December 15–19, 2009

20. Unbound systems along the neutron drip line
   A. Spyrou
   Workshop on Perspectives on the modern shell model and related experimental topics, Michigan State University, East Lansing, MI, February 4–6, 2010

21. Dissertation award in nuclear physics
   C. Hoffman
   American Physical Society April Meeting, Washington, D. C., February 13–16, 2010

22. Exploration of the neutron dripline and discovery of new isotopes
   M. Thoennessen
   Carpathian Summer School of Physics 2010, June 20–July 3, 2010, Sinaia, Romania

23. Beyond the driplines with nuclear reactions
   M. Thoennessen
   24\textsuperscript{th} International Nuclear Physics Conference, July 4–9, 2010, Vancouver, Canada

24. Undergraduate research with the MoNA Collaboration at the National Superconducting Cyclotron Laboratory
   B. Luther
   21\textsuperscript{st} International Conference on the Application of Accelerators in Research and Industry, CAARI, Fort Worth, TX, Aug. 8–13, 2010

25. Neutron decay spectroscopy at and beyond the limit of stability
   A. Spyrou
   The Limits of Existence of Light Nuclei, ECT* Workshop, October 25–30, 2010, Trento, Italy
26. Nuclear structure physics with MoNA-LISA  

27. New experimental work on structure beyond the neutron drip-line  
A. Spyrou 

28. Going beyond the dripline with MoNA-LISA  
M. Thoennessen 
1st Topical Workshop on Modern Aspects in Nuclear Structure Advances in Nuclear Structure with arrays including new scintillator detectors, February 22–25, 2012, Bormio, Italy

29. Exploration of light unbound nuclei  
M. Thoennessen 
Zakopane Conference on Nuclear Physics, August 27–September 2, 2012, Zakopane, Poland

30. Correlated two-neutron emission of nuclei beyond the neutron dripline  
M. Thoennessen 
4th International Conference on Collective Motion in Nuclei under Extreme Conditions COMEX 4, October 22–26, 2012, Shonan Village Center, Kanagawa, Japan

31. Recent results from MoNA-LISA  
Artemisia Spyrou 

32. Nuclear structure physics beyond the neutron drip line  
Artemisia Spyrou 
IWA.00001, Division of Nuclear Physics Fall Meeting, Newport Beach, CA, Bull. Am. Phys. Soc. 57 (2012)

33. Evidence for the ground-state resonance of $^{26}$O  
Zachary Kohley 
Direct Reactions with Exotic Beams (DREB) Workshop, Pisa, Italy, March 2012

34. Nuclear structure along the neutron drip line  
A. Spyrou 
8th Balkan School on Nuclear Physics, Bulgaria, July 3-12, 2012

35. Nuclear structure experiments beyond the neutron drip line  
Michael Thoennessen 
International Nuclear Physics Conference (INPC2013), Florence Italy, 2 - 7 June 2013

36. Measuring oxygen isotopes beyond the neutron dripline: Two-neutron emission and radioactivity  
Zachary Kohley 
APS Division of Nuclear Physics Fall Meeting, Newport News, VA, October, 2013

37. Simulation of a novel active target for neutron-unbound state measurements  
Nathan Frank Abstract DJ.00009, APS Division of Nuclear Physics Fall Meeting, Newport News, VA, October, 2013

38. Structure and decay correlations of two-neutron unbound systems beyond the dripline  
Zachary Kohley 
State of the Art in Nuclear Cluster Physics Workshop (SOTANCP3), Yokohama, Japan, May 2014

39. Three-body forces in two neutron decay experiments  
A. Spyrou 

40. Study of neutron-unbound states with MoNA-LISA  
M. Thoennessen 
8th International Workshop on Direct Reactions with Exotic Beams, June 30 - July 4, 2014, Darmstadt, Germany
41. Recent results from MoNA-LISA
   M. Thoennessen
   VII International Symposium on Exotic Nuclei, September 7-12, 2014, Kaliningrad, Russia

42. Neutron-unbound nuclei
   M. Thoennessen
   4th Joint Meeting of the APS Division of Nuclear Physics and the Physical Society of Japan, Oct. 7-11, 2014, Waikoloa, HI

Abstracts of talks and posters at conferences

1. MONA: The Modular Neutron Detector

2. Improving neutron detection efficiency by using passive converters

3. MONA: The Modular Neutron Detector

4. Construction of a Modular Neutron Array (MoNA)—A multi-college collaboration

5. The status of the MoNA project
   T. Baumann, MoNA Collaboration

6. MoNA: Detector development as undergraduate research
   Ruth Howes
   Workshop on Detector Development, Bloomington, IN, May 30, 2003

7. FPGA-based trigger logic for the Modular Neutron Array (MoNA)
   T. Baumann, P. A. DeYoung, MoNA Collaboration

8. Commissioning of the MSU/FSU sweeper magnet

9. Characteristics and preliminary results from MoNA at MSU/NSCL

10. How undergraduates from four-year departments can do “big” physics
    R. Howes for the MoNA Collaboration
    The Announcer 34, No. 4, 93 (2004)

11. Excitation and decay of neutron-rich Be isotopes
    W. Peters, MoNA Collaboration
12. Ground state wave function of $^{12}\text{Be}$  

13. Search for the first excited state of $^{24}\text{O}$  

14. First excited state of doubly-magic $^{24}\text{O}$  
N. Frank, A. Schiller, T. Baumann, J. Brown, P. DeYoung, J. Hinnefeld, R. Howes, J.-L. Lecouey, B. Luther, W. A. Peters, M. Thoennessen  

15. Population of neutron-unbound states from direct fragmentation  

16. Detection efficiency of the Modular Neutron Array  
T. Baumann, W. A. Peters, MoNA Collaboration  

17. Cosmic muon detection using the NSCL Modular Neutron Array  
W. F. Rogers, S. Mosby, S. Mosby, J. Gillette, M. Reese, MoNA Collaboration  

18. Study of Coulomb and nuclear dissociation for astrophysical neutron capture cross sections  

19. Ground state of $^{25}\text{O}$ and the first excited state of $^{24}\text{O}$  

20. Unbound states of neutron-rich oxygen isotope  

21. Measurement of the ground state of $^{12}\text{Be}$  

22. Investigating The N = 16 shell closure at the oxygen drip line  

23. Measurement of the efficiency of the Modular Neutron Array (MONA) at the NSCL  
CAARI (2008)

24. Studying the structure of the neutron-unbound $^{12}\text{Li}$  
A. Spyrou, M. Thoennessen, P. A. DeYoung, C. C. Hall, and the MoNA Collaboration  
25. Nuclear structure studies along the neutron drip line: The case of $^{22}$N
   A. Spyrou and the MoNA Collaboration
   8th International Conference on Radioactive Nuclear Beams (RNB8), Grand Rapids, MI, USA, 26–30 May 2009

26. Studying the neutron unbound $^{18}$B
   A. Russel, N. Frank, E. Breitbach, R. Howes, W. A. Peters, A. Schiller, MoNA Collaboration

27. Disappearance of the N = 14 shell
   M. J. Strongman, T. Baumann, D. Bazin, N. Frank, S. Mosby, W. A. Peters, A. Schiller, A. Spyrou, M. Thoennessen, C. R. Hoffman,
   S. L. Tabor, J. Brown, P. A. DeYoung, J. E. Finck, W. F. Rogers

28. Creating a collaboration to perform big science at small schools
   Joseph E. Finck, Bryan Luther, and Graham Peaslee
   CUR 13th Nation Conference, Undergraduate Research as Transformative Practice, June 19–22, 2010, Weber State University, Ogden UT

29. Impact of undergraduate research experiences on graduate research programs (panel discussion)
   Michael Thoennessen

30. Spectroscopy of neutron-unbound fluorine isotopes
   MoNA Collaboration

31. Ground-state neutron decay of $^{21}$C
   S. Mosby, M. Thoennessen, P. DeYoung

32. Nuclear structure along the neutron dripline
   A. Spyrou, MoNA Collaboration
   Nuclear Structure 2010, Clark-Kerr Campus U. C. Berkeley, CA, 8–13 August 2010

33. Construction and testing of the Large multi-Institutional Scintillator Array (LISA) – A model of collaborative undergraduate research
   Warren Rogers and the MoNA Collaboration

34. Spectroscopy of neutron unbound fluorine
   oung, MoNA Collaboration

35. Measurement of excitation energy of neon prefragments
   M. Mosby, D. J. Morrissey, M. Thoennessen

36. Spectroscopy of neutron unbound carbon isotopes
   S. Mosby, M. Thoennessen, P. DeYoung

37. Spectroscopy of neutron-unbound $^{15}$Be
   Jesse Snyder, Michael Thoennessen, Thomas Baumann, Artemis Spyrou, Michael Strongman, Greg Christian, Shea Mosby, Michelle Mosby,
   Jenna Smith, Anna Simon, Bryan Luther, Sharon Stephenson, Alex Peters, Paul DeYoung, Eric Lunderberg, Joseph Finck

38. Fast fragmentation studies with the MoNA and LISA neutron detectors
   Joseph E. Finck and the MoNA Collaboration
   XII International Symposium on Nuclei in the Cosmos, Cairns, Australia (August 5–10, 2012)
39. Unbound excited states in $^{28}\text{Ne}$ and $^{25}\text{F}$
   Jenna Smith, B. Alex Brown, Greg Christian, Shea Mosby, John F. Novak, Steven J. Quinn, Jesse Snyder, Artemis Spyrou, Michael J. Strongman, Michael Thoennessen, Thomas Baumann, Zachary Kohley, Joseph E. Finck, and Calem R. Hoffman
   DD.00003, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

40. Spectroscopy of neutron-unbound $^{15}\text{Be}$
   Jesse Snyder, Michael Thoennessen, Thomas Baumann, Artemis Spyrou, Michael Strongman, Greg Christian, Shea Mosby, Michelle Mosby, Jenna Smith, Anna Simon, Bryan Luther, Sharon Stephenson, Alex Peters, Paul DeYoung, Eric Lunderberg and Joseph Finck
   CD.00009, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

41. The controversial $^{10}\text{He}$ ground state resonance: A new observation using a 2p2n-removal from $^{14}\text{Be}$
   Z. Kohley, J. Snyder and M. Thoennessen
   CD.00005, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

42. Simulation of a novel active target for neutron-unbound state measurements
   Nathan Frank
   Abstract DJ.00009, APS Division of Nuclear Physics Fall Meeting, Newport News, VA, October, 2013

43. Measuring the partial width of the $^{56}\text{Ni}$ proton-capture resonance through (d,n) with VANDLE and MoNA-LISA
   Abstract CF.00001, APS Division of Nuclear Physics Fall Meeting, Newport News, VA, October, 2013

44. 4n contributions in populating unbound $^{10}\text{He}$ from $^{14}\text{Be}$
   Michael Jones, Zach Kohley, Jesse Snyder, Thomas Baumann, Jenna Smith, Artemis Spyrou, Michael Thoennessen
   Abstract PD.00004, APS Division of Nuclear Physics Fall Meeting, Newport News, VA, October, 2013

45. Two-neutron decay of excited states of $^{11}\text{Li}$
   J. Smith, MoNA Collaboration

46. Measurement of neutron knockout cross-section of $^{24}\text{O}$ to the ground-state of $^{23}\text{O}$

47. Two-neutron decay from the ground state of $^{26}\text{O}$
   H. Attanayake, P. King, C. Brune, D. Diaratne, MoNA Collaboration

48. A Multi-layered target for the study of neutron-unbound nuclei
   Paul Gueye, Nathan Frank and Michael Thoennessen

49. Measurement of neutron knockout cross section of $^{24}\text{O}$ to the ground-state of $^{23}\text{O}$
   D. Diaratne, C. Brune, P. King, H. Attanayake, S. Grimes, and M. Thoennessen

50. VANDLE-izing north america; first results from the versatile array of neutron detectors at low energy
   INPC2013 Book of Abstracts, NF070 (2013)

51. Experimental check of Coulomb dissociation method for neutron capture measurements
52. Determining the resonance strength of the $^{56}$Ni $r\beta$-process waiting point through (d,n) with VANDLE and MoNA-LISA


Abstract K6.00008, American Physical Society, Savannah, Georgia, April 2014

Abstracts of standard talks and posters at conferences by undergraduates

1. Accurate energy calibrations from cosmic ray measurements
   A. DeLine, J. Finck, A. Spyrou, M. Thoennessen, and P. DeYoung

2. Nuclear astrophysics outreach program now employs researcher’s equipment for enhancement
   Amy DeLine, Zach Constan, and Joseph Finck
   Winter Meeting of the AAPT, Chicago, IL (2009)

3. Undergraduate experiences in cutting-edge research experiments
   A. Haagsma, K. Rethman, MoNA Collaboration

4. Spectroscopy of $^{13}$Li

Seminars and colloquia

1. MoNA: the Modular Neutron Array
   Joseph E. Finck
   Physics Department Seminar, Central Michigan University, Mount Pleasant, MI, October 25, 2001

2. Physics at the neutron dripline: The MoNA Project and the NSCL
   Bryan Luther
   Department of Physics Seminar, North Dakota State University, Fargo, ND, October 16, 2002

3. Giving students a taste of research
   Bryan Luther
   Department of Physics Seminar, North Dakota State University, Fargo, ND, October 16, 2002

4. The Coupled Cyclotron Facility and MoNA at the NSCL
   Thomas Baumann
   Triangle Universities Nuclear Laboratory Seminar, Durham, NC, November 21, 2002

5. MoNA: The Modular Neutron Array
   Bryan Luther
   Centennial Scholars Program, Moorhead, MN, February 11, 2003

6. Development of neutron detectors
   Ruth Howes
   Seminar at Mt. San Antonio College, Walnut, CA, March 28, 2003

7. MoNA: detector development as undergraduate research
   Ruth Howes
   Workshop on Detector Development, Bloomington, IN, May 30, 2003

8. MoNA and physics at the nuclear dripline
   Ruth Howes
   Colloquium at Marquette University, Milwaukee, WI, January 29, 2004
9. Status of the Modular Neutron Array, new opportunities near the neutron dripline
   James A. Brown
   Ball State University, Muncie, IN, November 11, 2004

10. Where the sidewalk ends: MoNA and the neutron dripline
    Bryan Luther
    Physics Department Colloquium, Carleton College, Northfield, MN, March 10, 2005

11. Exploring the neutron dripline with MoNA
    Michael Thoennessen
    Physics Department Colloquium, Argonne National Laboratory, Argonne, IL, February 3, 2006

12. Nuclear structure studies with the Modular Neutron Array
    James A. Brown
    Duke University, Triangle Universities Nuclear Structure Laboratory, Durham, NC, March 2, 2006

13. The Modular Neutron Array & the MoNA collaboration
    Thomas Baumann
    Physics Department Seminar, Central Michigan University, Mount Pleasant, MI, March 30, 2006

14. Selective population and neutron decay of the first excited state of semi-magic $^{23}$O
    A. Schiller
    Nuclear Physics Seminar, Argonne National Laboratory, Argonne, IL, December 18, 2006

15. Physics with the Modular Neutron Array
    Joseph E. Finck
    Physics Department Seminar, Central Michigan University, Mount Pleasant, MI, January 11, 2007

16. Exploring the edge of the nuclear universe
    Michael Thoennessen
    Physics Department Colloquium, Smith College, Northampton, MA, February 17, 2007

17. Nuclear physics near the dripline: Present and future of MoNA
    Nathan Frank
    Physics Department Seminar, Central Michigan University, Mount Pleasant, MI, March 23, 2007

18. Exploring the edge of the nuclear universe
    Michael Thoennessen
    Seminar, Department of Biological & Physical Sciences, South Carolina State University, Orangeburg, SC, February 26, 2008

19. Studying exotic nuclei with the Modular Neutron Array (MoNA)
    Artemis Spyrou
    Seminar, Physics Department, Indiana University South Bend, November 13, 2008

20. Explorations of the driplines at the NSCL
    Michael Thoennessen
    College 3 Seminar, Institute Laue Langevin, Grenoble, France, November 21, 2008

21. Studying exotic nuclei with the Modular Neutron Array (MoNA)
    Artemis Spyrou
    Seminar, Department of Physics, Grand Valley State University, November 2, 2009

22. Discovery of new isotopes at and beyond the neutron dripline
    Michael Thoennessen
    Kernphysikalisches Kolloquium, Institut für Kernphysik, Universität zu Köln, Germany, February 3, 2010

23. Traveling beyond the neutron dripline with MoNA
    A. Spyrou
    Seminar given at Oakridge National Lab, June 2010
24. Physics at the neutron dripline  
Sharon Stephenson  
Physics Department Colloquium, Franklin and Marshall College, Lancaster, PA, October 13, 2011

25. Construction, testing, and installation of the Large Multi-Institutional Scintillator Array (LISA)  
D. A. Meyer  
University of Kentucky, Lexington, KY, 21 April 2011

26. Exploring the edge of the nuclear universe  
Michael Thoennessen  
Seminar, Dept. of Physics and Astronomy, Indiana University South Bend, South Bend, IN, February 10, 2011

27. Exploring the edge of the nuclear universe  
Michael Thoennessen  
Muller Prize Lecture, Ohio Wesleyan University, Delaware, OH, Feb. 22, 2011

28. Expanding the nuclear horizon  
Michael Thoennessen  
Department of Physics & Astronomy Colloquium, Stony Brook University, Stony Brook, NY, March 1, 2011

29. Expanding the nuclear horizon  
Michael Thoennessen  
iThemba Laboratory Colloquium, Stellenbosch, South Africa, March 8, 2011

30. Physics at the neutron dripline  
Sharon Stephenson  
Franklin and Marshall College, October 13, 2011

31. Undergraduate research in nuclear physics  
Nathan Frank  
Indiana University South Bend, South Bend, IN, March 8, 2012

32. MoNA-LISA and the rare, shortlived world of exotic nuclei  
Sharon Stephenson  
SUNY-Geneseo, April 12, 2012

33. Going beyond the neutron dripline: Recent measurements of two-neutron unbound nuclei  
Zachary Kohley  
Webinar for the Nuclear Science and Security Consortium, October 2012

34. First observation of ground state di-neutron decay: $^{16}$Be  
A. Spyrou  
Seminar given at NSCL, February 2012

35. Nuclear structure along the neutron drip line: recent results of MoNA  
A. Spyrou  
Seminar at Argonne National Lab, April 2012

36. Nuclear structure along the neutron dripline  
A. Spyrou  
Colloquium at Fermi Lab, September 2012

37. Research on unstable atomic nuclei with undergraduates  
Nathan Frank  
Celebration of Scholarship at Augustana College, February 18, 2013

38. Neutron-rich nuclear physics at Michigan State University  
Jenna Smith  
Seminar, Indiana University - South Bend, March 28, 2013

39. Measuring oxygen isotopes beyond the neutron dripline: Two-neutron emission and radioactivity  
Zachary Kohley  
Australian National University, Canberra, Australia, November 2013
40. Measuring oxygen isotopes beyond the neutron dripline: Two-neutron emission and radioactivity
   Zachary Kohley
   Central Michigan University, Mount Pleasant, MI, September 2013

41. Studying Atomic Nuclei with Undergraduates
   Nathan Frank
   Colloquium, Department of Physics, Hampton University, Hampton, VA, April 3, 2014

42. Making Beautiful Physics with the Help of MoNA-LISA
   Sharon Stephenson
   Ithaca College April 28, 2015.

43. The unbound nuclei and the dineutron.
   Bryan A. Luther
   Concordia College, April 10, 2015.

44. The MoNA collaboration and undergraduate education.
   Paul A. DeYoung

Undergraduate presentations: CEU posters

CEU, 2002 DNP Fall Meeting, East Lansing, MI

1. Veto detectors for the micro-modular neutron array
   Y. Lu, T. Baumann, M. Thoennessen, E. Tryggestad, M. Evanger, B. Luther, M. Rajabali, R. Turner

2. First radioactive beam experiment with the Modular Neutron Array MoNA
   M. Rajabali, M. Evanger, R. Turner, B. Luther, T. Baumann, Y. Lu, M. Thoennessen, E. Tryggestad

3. Neutron testing of the micro-Modular Neutron Array
   M. Evanger, M. Rajabali, R. Turner, B. Luther, T. Baumann, Y. Lu, M. Thoennessen, E. Tryggestad

4. Cosmic ray testing of the micro-Modular Neutron Array
   R. Turner, M. Evanger, M. Rajabali, B. Luther, T. Baumann, Y. Lu, M. Thoennessen, E. Tryggestad

5. The MoNA project

CEU, 2003 DNP Fall Meeting, Tucson, AZ

1. Calibration of the Modular Neutron Array (MoNA)
   S. Clark, N. Walker, W. Rogers, T. Baumann, M. Thoennessen, A. Stolz, W. Peters

2. High voltage control of the Modular Neutron Array
   S. Marley, T. Baumann, N. Frank, E. Johnson, W. Peters, M. Thoennessen, B. Luther

3. Cosmic rays in MoNA
   E. Johnson, M. Thoennessen, T. Baumann, W. Peters, S. Marley, B. Luther
CEU, 2004 DNP Fall Meeting, Chicago, IL

1. Determination of position resolution for the Modular Neutron Array using cosmic rays
   J. Miller, M. Kleber, B. Luther, MoNA Collaboration

2. MoNA and initial measurements with $^7$He resonance
   T. Pike, R. Pepin, MoNA Collaboration

3. Cosmic muon tracking with MoNA
   K. Watters, L. Elliott, M. Strongman, W. Rogers

4. Calibration of the Modular Neutron Array
   R. Pepin, T. Pike, MoNA Collaboration

CEU, 2005 DNP Fall Meeting, Maui, HI

1. Tracking single and multiple events in MoNA
   A. Stump, A. Ratkiewicz, MoNA Collaboration

2. MoNA calibration and neutron tracking
   S. Mosby, E. Mosby, W. F. Rogers, MoNA Collaboration

CEU, 2006 DNP Fall Meeting, Nashville, TN

1. An automated relative time calibration for MoNA
   D. Albertson, MoNA Collaboration

2. Analysis of kinematics and decay energy in the breakup of $^7$He
   D. Denby, P. DeYoung, G. Peaslee, MoNA Collaboration

3. Calibration of the thick and thin scintillators for the NSCL/FSU Sweeper magnet system
   A. Hayes, MoNA Collaboration

4. Cosmic muon flux variations using the Modular Neutron Array
   E. Mosby, S. Mosby, J. Gillette, M. Reese, W. F. Rogers, MoNA Collaboration

5. Neutron multiplicity discrimination in MoNA
   S. Mosby, E. Mosby, W. F. Rogers, MoNA Collaboration

CEU, 2007 DNP Fall Meeting, Newport News, VA

1. Search for upward cosmic rays
   E. White, A. Spyrou, M. Thoennessen, T. Yoast-Hull, MoNA Collaboration

2. Efficiency and multi-hit capability improvements of MoNA
   T. Yoast-Hull, A. Spyrou, M. Thoennessen, E. White, MoNA Collaboration
CEU, 2008 DNP Fall Meeting, Oakland, CA

1. Geant4 simulation of MoNA
   A. Fritsch, M. Heim, T. Baumann, S. Mosby, A. Spyrou

2. Investigation of neutron scattering in the Modular Neutron Array (MoNA)
   M. Gardener, W. F. Rogers

3. Experimental observation of decay energy of $^{12,13}$Li
   C. Hall, P. A. DeYoung, S. Mosby, A. Spyrou, M. Thoennessen

CEU, 2009 DNP Fall Meeting, Waikoloa, HI

1. Spectroscopy of $^{12}$Li
   E. Lunderberg, C. Hall, P. DeYoung, A. Spyrou, M. Thoennessen, MoNA Collaboration

2. Observation of neutron-unbound resonant stated in $^{23}$O and $^{28}$Ne

3. Non-resonant neutron emission of excited neutron-rich nuclei

4. Accurate position calibration for charged fragments

CEU, 2010 DNP Fall Meeting, Santa Fe, NM

1. Testing the Large-area multi-Institutional Scintillator Array (LISA) neutron detector
   CEU Poster EA.00078, Division of Nuclear Physics Fall Meeting, Santa Fe, NM (2010)

2. Performance comparison of MoNA and LISA neutron detectors
   Kimberly Purtell, Kaitlyne Rethman, Autumn Haagsma, Joseph Finck, Jenna Smith, Jesse Snyder
   CEU Poster EA.00090, Division of Nuclear Physics Fall Meeting, Santa Fe, NM (2010)

3. Construction of the Large-area multi-Institutional Scintillator Array (LISA) neutron detector
   Kaitlyne Rethman, Kimberly Purtell, Autumn Haagsma, Casey DeRoo, Megan Jacobson, Steve Kuhn, Alexander Peters, Tim Nagi, Sam Stewart, Zack Torstrick, Mathieu Ndong, Rob Anthony, Hengzhi Chen, Alex Howe, Nicholas Badger, Matthew Miller, Brad Vest, Ben Foster, Logan Rice, Alegra Aulie, Amanda Grovom, Philip Kasavan, Lewis Elliott
   CEU Poster EA.00093, Division of Nuclear Physics Fall Meeting, Santa Fe, NM (2010)

4. Search for angular anisotropies in neutron emissions of fragmentation reactions with secondary beams
   Sam Novario, Greg Christian, Jenna Smith, Michael Thoennessen
   CEU Poster EA.00081, Division of Nuclear Physics Fall Meeting, Santa Fe, NM (2010)

5. Tagging the decay of neutron unbound states near the dripline
   Alissa Wersal, Greg Christian, Michael Thoennessen, Artemis Spyrou
   CEU Poster EA.00126, Division of Nuclear Physics Fall Meeting, Santa Fe, NM (2010)

6. Analysis of an experiment on neutron-rich isotopes
   CEU Poster EA.00005, Division of Nuclear Physics Fall Meeting, Santa Fe, NM (2010)

7. MoNA and two-neutron decay analysis
   Amanda Grovom, Alegra Aulie, Warren F. Rogers
   CEU Poster EA.00007, Division of Nuclear Physics Fall Meeting, Santa Fe, NM (2010)
1. Modeling neutron events in MoNA-LISA using MCNPX
   Margaret Kendra Elliston, Alexander Peters, Kristen Stryker, Sharon Stephenson, MoNA Collaboration
   CEU Poster EA.00039, Division of Nuclear Physics Fall Meeting, East Lansing, MI (2011)

2. Calibration of the MoNA and LISA arrays for the LISA commissioning experiment
   A. Grovom, J. Kwiatkowski, W. F. Rogers, MoNA Collaboration
   CEU Poster EA.00058, Division of Nuclear Physics Fall Meeting, East Lansing, MI (2011)

3. Calibration of the sweeper chamber charged-particle detectors for the LISA commissioning experiment
   J. Kwiatkowski, A. Grovom, W. Rogers, Westmont College, MoNA Collaboration
   CEU Poster EA.00073, Division of Nuclear Physics Fall Meeting, East Lansing, MI (2011)

4. Optical attenuation in MoNA and LISA detector elements
   Logan Rice, Jonathan Wong, MoNA Collaboration
   CEU Poster EA.00112, Division of Nuclear Physics Fall Meeting, East Lansing, MI (2011)

5. Testing and installation of a high efficiency CsI scintillator array
   Natalie Viscariello, Stuart Casarotto, Nathan Frank, Jenna Smith, Michael Thoennessen
   CEU Poster EA.00135, Division of Nuclear Physics Fall Meeting, East Lansing, MI (2011)

1. Simulating neutron interactions in the MoNA-LISA/Sweeper setup with Geant4
   Magdalene MacArthur
   CEU Poster EA.00054, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

2. Analysis of LISA commissioning run data for study of $^{24}O$ excited state decay energies
   N. Taylor, S. Garrett, A. Barker and W. F. Rogers
   CEU Poster EA.00060, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

3. Calibration of charged-particle detectors for the LISA commissioning experiment
   S. Garrett, N. Taylor, A. Barker and W. Rogers
   CEU Poster EA.00059, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

4. Active target simulation
   Nathan Smith, Peter Draznik and Nathan Frank
   CEU Poster EA.00003, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

5. Exploration of three-body decay using jacobian coordinates
   Mark Hoffmann, Kyle Williams and Nathan Frank
   CEU Poster EA.00002, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

6. Composition of the $^{24}O$ ground state wave function
   CEU Poster EA.00066, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

7. Preparation for MoNA/LISA VANDLE $^{64}Ni(d,n)$ experiment at the NSCL
   CEU Poster EA.00071, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2012)

1. Precise timing calibration for MoNA and LISA detectors
   Sierra Garrett, Alyson Barker, Nathaniel Taylor, Warren F. Rogers
   CEU Poster EA.00062, Division of Nuclear Physics Fall Meeting, Newport News, VA (2013)

2. Isotope separation and decay energy calculation for LISA commissioning experiment
   Nathaniel Taylor, Alyson Barker, Sierra Garrett, Warren F. Rogers
   CEU Poster EA.00063, Division of Nuclear Physics Fall Meeting, Newport Beach, CA (2013)
3. Commissioning a hodoscope detector
   Andrew Lulis, Abdul Merhi, Nathan Frank, Daniel Bazin, Jenna Smith, Michael Thoennessen
   CEU Poster EA.00072, Division of Nuclear Physics Fall Meeting, Newport News, VA, October, 2013

4. Segmented target design
   Abdul Rahman Merhi, Nathan Frank, Paul Gueye, Michael Thoennessen
   CEU Poster EA.00074, Division of Nuclear Physics Fall Meeting, Newport News, VA, October, 2013

5. Converting VANDLE data into ROOT for merging with other systems
   CEU Poster EA.00080, Division of Nuclear Physics Fall Meeting, Newport News, VA, October, 2013

CEU, 2014 DNP Fall Meeting, Waikoloa, HI

1. Detector calibrations for fragmentation reactions with relativistic heavy ions at the NSCL
   Heather Garland, Sharon Stephenson, Michelle Mosby
   CEU Poster GB.00042, Division of Nuclear Physics Fall Meeting, Waikoloa, HI October, 2014

2. Unbound Resonances in Light Nuclei
   Elizabeth Havens, Joseph Finck, Paul Gueye, Michael Thoennessen
   CEU Poster GB.00041, Division of Nuclear Physics Fall Meeting, Waikoloa, HI October, 2014

3. Decay energies for $^{24}\text{O} \rightarrow ^{23}\text{O} + n$ using MoNA-LISA-Sweeper detector systems and Monte Carlo simulations
   Sierra Garrett, Alyson Barker, Rachel Parkhurst, Warren Rogers, Anthony Kuchera
   CEU Poster GB.00043, Division of Nuclear Physics Fall Meeting, Waikoloa, HI October, 2014

Regional undergraduate presentations: Talks and other posters

1. The MoNA project
   U. Onwuemene and T. Grant
   Illinois Section of the AAPT Fall Meeting, Decatur, IL, October 18–19, 2002

2. The MoNA project
   M. R. Evanger and R. E. Turner
   Minnesota Area Association of Physics Teachers Fall Meeting, Morris, MN, October 25–26, 2002

3. Calibration of organic scintillator bars for the Modular Neutron Detector Array
   J. W. Longacre
   Indiana Section of the AAPT Spring Meeting, Bloomington, IN, April 25–26, 2003

4. Neutron detection by the Modular Neutron Array (MoNA)
   D. McCollum
   Indiana Section of the AAPT Spring Meeting, Bloomington, IN, April 25–26, 2003

5. Experimental developments along the neutron dripline
   J. Robertson
   Indiana Section of the AAPT Spring Meeting, Bloomington, IN, April 25–26, 2003

6. Tracking single and multiple neutron events in the Modular Neutron Array
   A. Ratkiewicz
   Society of Physics Students, Zone 9 Fall 2005 Meeting, Marquette University, Milwaukee WI, October 13–14, 2005

7. Tracking single and multiple neutron events in the Modular Neutron Array
   A. Ratkiewicz
   Joint Meeting of the 16th Annual Argonne Symposium for Undergraduates in Science, Engineering and Mathematics & the Central States Universities, incorporated (CSUI), November 4–5, 2005

8. Tracking single and multiple neutron events in the Modular Neutron Array
   A. Ratkiewicz
   20th National Conference on Undergraduate Research, Asheville, NC, April 5–8, 2006
9. Accurate energy calibrations from cosmic ray measurements
   A. DeLine
   Posters at the Capitol, Capitol Rotunda, Lansing, Michigan, April 16, 2008

10. Observation of a resonance state in $^{25}$F
    Alison R. Smith, Mark S. Kasperczyk, Nathan H. Frank

11. Observation of a resonance state in $^{25}$F
    Alison R. Smith, Mark S. Kasperczyk, Nathan H. Frank
    Spring Meeting of the Illinois Section of the AAPT, Illinois Wesleyan University, Bloomington, Illinois, April 3–4, 2009

12. Observation of a resonance state in $^{26}$F
    Mark S. Kasperczyk, Alison R. Smith, Nathan H. Frank
    Spring Meeting of the Illinois Section of the AAPT, Illinois Wesleyan University, Bloomington, Illinois, April 3–4, 2009

13. Assembly and testing of the Large Area Multi-Institutional Array: LISA
    Mathieu Ndong, Samuel Stewart, and Zachary Torstrick
    Notre Dame Science and Engineering Summer Research Symposium, August 6, 2010

14. Assembly and testing of scintillation neutron detectors for LISA
    Alex R. Howe
    Ohio Five Summer Science Research Symposium, Ohio Wesleyan University, Delaware, OH, July 23, 2010

15. Assembly and testing of LISA neutron detectors
    Robert E. Anthony
    Ohio Five Summer Science Research Symposium, Ohio Wesleyan University, Delaware, OH, July 23, 2010

16. Assembly and testing of the Large Area multi-Institutional Scintillator Array (LISA)
    Zachary Torstrick, Samuel Stewart, Mathieu Ndong

17. Analysis of neutron-rich isotopes
    Natalie Viscariello
    Celebration of Learning, Augustana College, Rock Island, IL, May 5, 2012

18. Testing and installation of a high-efficiency CsI scintillator array
    Stuart Casarotto
    Celebration of Learning, Augustana College, Rock Island, IL, May 5, 2012

19. Active target simulation
    Nathan Smith
    2012 Quadrennial Physics Congress, Orlando, FL, Nov. 8-10, 2012

20. Testing and installation of a high efficiency CsI scintillator array
    Natalie Viscariello
    2012 Quadrennial Physics Congress, Orlando, FL, Nov. 8-10, 2012

21. Active target simulation
    Nathan Smith
    Celebration of Learning, Augustana College, Rock Island, IL, Jan. 29, 2013

22. Testing and efficiency of a high efficiency CsI scintillator array
    Natalie Viscariello
    Sigma Xi Research Presentations, Augustana College, Rock Island, IL, Jan. 29, 2013

23. Exploration of three-body decay using Jacobian coordinates
    Mark Hoffmann
    Sigma Xi Research Presentations, Augustana College, Rock Island, IL, Jan. 29, 2013
24. Exploration of three-body decay using Jacobian coordinates
Mark Hoffmann and Kyle Williams
Sigma Xi Research Presentations, Augustana College, Rock Island, IL, May 4, 2013

Joseph Bullaro
Celebration of Learning, Augustana College, Rock Island, IL, May 6, 2015

MoNA in the media

1. MoNA: The Modular Neutron Array Video
Bryan Luther
Centennial Scholars Program, Moorhead, MN, February 11, 2003

2. Undergraduates assemble neutron detector
T. Feder
Physics Today, p. 25, March 2005

3. Undergraduates as researchers
MoNA Collaboration
http://chronicle.com/subscribe/login?url=/weekly/v53/i33/33b02102.htm

4. Raising MoNA
A. Jia
Symmetry Vol. 4 p. 6 Aug. 2007
http://www.symmetrymagazine.org/cms/?pid=1000511

5. Giving students a taste of research
M. Thoennessen
Physics World, p. 16, Feb. 2008

6. Going beyond the neutron drip-line with MoNA
J. A. Brown for the MoNA Collaboration
Nuclear Physics News 20, p. 23, 2010

7. Focus: Nuclei emit paired-up neutrons
Michael Schirber
Physics 5, 30 (2012)

8. MoNA makes first confirmed sighting of dineutron decay
CERN COURIER, April 27 (2012)
cerncourier.com/cws/article/cern/49341

9. Michigan’s MoNA LISA
http://nscl.msu.edu/general-public/news/2012/michigan039s-mona-lisa

10. MoNA makes first confirmed sighting of dineutron decay. CERN COURIER, April 27, 2012
http://cerncourier.com/cws/article/cern/49341

11. R&D News April 16, 2012
http://goo.gl/EWIxd1

12. Dineutron emission seen for the first time

13. Unknown form of nuclear decay
Popular Science, Science and Technology Portal. May 9, 2012 http://popular-science.net/tag/dineutron
http://physicsworld.com/cws/article/news/2012/mar/14/dineutron-emission-seen-for-the-first-time
MoNA on the web

1. The MoNA homepage
   http://www.cord.edu/dept/physics/mona/

2. MoNA Wikipedia article
   http://en.wikipedia.org/wiki/Modular_Neutron_Array

3. MoNA YouTube video
   http://www.youtube.com/watch?v=qPlsFu5m41s

4. MoNA on Facebook
   http://www.facebook.com/pages/Modular-Neutron-Array/143503835659905

5. Research.gov insights into nuclear decay
   http://goo.gl/hQw3O8

Publications in refereed journals

1. Using passive converters to enhance detection efficiency of 100-MeV neutrons

2. MONA—The Modular Neutron Array

3. Fabrication of a modular neutron array: A collaborative approach to undergraduate research
   American Journal of Physics 73, 122 (2005)

4. Construction of a Modular Large-Area Neutron Detector for the NSCL

5. Selective population and neutron decay of an excited state of $^{23}$O

6. Production of nuclei in neutron unbound states via primary fragmentation of $^{48}$Ca

7. Big physics at small places: The Mongol horde model of undergraduate research
   P. J. Voss, J. E. Finck, R. Howes, J. Brown, T. Baumann, A. Schiller, M. Thoennessen, P. A. DeYoung, G. Peaslee, J. Hinnefeld, B. Luther, P. V. Pancell, W. F. Rogers

8. Determination of the N = 16 shell closure at the oxygen drip line

*undergraduate student
9. Ground state energy and width of $^7\text{He}$ from $^8\text{Li}$ proton knockout

10. Neutron decay spectroscopy of neutron-rich oxygen isotopes

11. Evidence for a doubly magic $^{24}\text{O}$

12. Disappearance of the $N = 14$ shell

13. First evidence for a virtual $^{18}\text{B}$ ground state

14. First observation of excited states in $^{12}\text{Li}$

15. Observation of a two-neutron cascade from a resonance in $^{24}\text{O}$

16. Neutron knockout of $^{12}\text{Be}$ populating neutron-unbound states in $^{11}\text{Be}$

17. Neutron unbound states in $^{25,26}\text{F}$

18. Search for the $^{15}\text{Be}$ ground state

19. Nuclear structure at and beyond the neutron drip line
    T. Baumann, A. Spyrou, and M. Thoennessen

20. First observation of ground state dineutron decay: $^{16}\text{Be}$

21. Evidence for the ground-state resonance of $^{26}\text{O}$
22. Exploring the low-Z shore of the island of inversion at $N = 19$

23. Modeling interactions of intermediate-energy neutrons in a plastic scintillator array with GEANT4

24. Spectroscopy of neutron-unbound $^{27,28}$F

25. Reply to “Comment on: ‘Neutron knockout of $^{12}$Be populating neutron-unbound states in $^{11}$Be””

26. Reply to “Comment on: ‘First observation of ground state dineutron decay: $^{16}$Be.’”

27. Unresolved question of the $^{10}$He ground state resonance

28. Neutron unbound states in $^{28}$Ne and $^{25}$F

29. First observation of $^{13}$Li ground state

30. Study of two-neutron radioactivity in the decay of $^{26}$O

31. Observation of a low-lying neutron-unbound state in $^{19}$C

32. Novel techniques to search for one- and two-neutron radioactivity
M. Thoennessen, G. Christian, Z. Kohley, T. Baumann, M. Jones, J. K. Smith, J. Snyder, A. Spyrou,

33. First observation of $^{15}$Be

34. Exploiting neutron-rich radioactive ion beams to constrain the symmetry energy
Z. Kohley, G. Christian, T. Baumann, P. A. DeYoung, J. E. Finck, N. Frank, M. Jones, J. K. Smith, J. Snyder, A. Spyrou, and M. Thoennessen,
35. Search for $^{21}\text{C}$ and constraints on $^{22}\text{C}$

36. Determining the $^7\text{Li}(n,\gamma)^{8}\text{Li}$ cross section via Coulomb dissociation of $^{8}\text{Li}$

37. Low-lying neutron unbound states in $^{12}\text{Be}$

38. Selective population of unbound states in $^{10}\text{Li}$
J.K. Smith, T. Baumann, J. Brown, P. A. DeYoung, N. Frank, J. Hinnefeld, Z. Kohley, B. Luther, B. Marks*, A. Spyrou, S. L. Stephenson, M. Thoennessen, and S. J. Williams,

39. Search for unbound $^{15}\text{Be}$ states in the $3n+^{12}\text{Be}$ channel

40. Three-body correlations in the ground-state decay of $^{26}\text{O}$
Z. Kohley, T. Baumann, G. Christian, P. A. DeYoung, J. E. Finck, N. Frank, B. Luther, E. Lunderberg, M. Jones, S. Mosby, J. K. Smith, A. Spyrou, and M. Thoennessen,

41. Further insights into the reaction $^{14}\text{Be}(\text{CH}_2, X)^{10}\text{He}$

42. Population of $^{13}\text{Be}$ in nucleon exchange reactions

43. Neutron correlations in the decay of excited $^{11}\text{Li}$
J.K. Smith, T. Baumann, D. Bazin, J. Brown, P. A. DeYoung, M. D. Jones, Z. Kohley, B. Luther, B. Marks*, A. Spyrou, S. L. Stephenson, M. Thoennessen, and A. Volya,

44. Unbound excited states of the $N = 16$ closed-shell nucleus $^{24}\text{O}$

Conference proceedings

1. MONA: The Modular Neutron Array at the NSCL
2. First results from MoNA

3. Can the neutron capture cross sections be measured with Coulomb dissociation?

4. Observation of the first excited state in $^{23}\text{O}$

5. Exploring neutron-rich oxygen isotopes with MoNA

6. Population of neutron unbound states via two-proton knockout reactions

7. Efficiency of the Modular Neutron Array (MoNA)

8. Nuclear structure physics with MoNA-LISA

9. Exploring the neutron dripline two neutrons at a time: The first observations of the $^{26}\text{O}$ and $^{16}\text{Be}$ ground state resonances

10. New measurements of the properties of neutron-rich projectile fragments

11. Observation of ground-state two-neutron decay
12. Structure and decay correlations of two-neutron systems beyond the dripline

13. Study of Neutron-Unbound States with MoNA
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Year</th>
<th>Spokesperson</th>
<th>Title</th>
<th>Status</th>
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<tbody>
<tr>
<td>discretionary</td>
<td>2002</td>
<td></td>
<td>micro MoNA</td>
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<tr>
<td>04503</td>
<td>2004</td>
<td>N. Frank</td>
<td>Sweeper magnet test</td>
<td>[13]</td>
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<tr>
<td>03048</td>
<td>2004</td>
<td>J. Finck</td>
<td>Ground state wave function of $^{12}$Be</td>
<td>[21–23]</td>
</tr>
<tr>
<td>03038</td>
<td>2005</td>
<td>A. Kiss</td>
<td>Coulomb-breakup of neutron-rich nuclei</td>
<td>[31, 32]</td>
</tr>
<tr>
<td>05502</td>
<td>2005</td>
<td>P. DeYoung</td>
<td>$^7$He breakup</td>
<td>[33]</td>
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<tr>
<td>05039</td>
<td>2005</td>
<td>P. DeYoung</td>
<td>Going beyond the $N = 16$ shell in oxygen</td>
<td>[34–38]</td>
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<tr>
<td>05033</td>
<td>2005</td>
<td>P. DeYoung</td>
<td>Population of neutron-unbound states from direct fragmentation, test</td>
<td>completed (see 05124)</td>
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<tr>
<td>05034</td>
<td>2006</td>
<td>A. Schiller</td>
<td>Two-neutron decay of $^{13}$Li</td>
<td>[39, 40]</td>
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<tr>
<td>06504</td>
<td>2006</td>
<td>M. Thoennessen</td>
<td>Sweeper magnet beam blocker test</td>
<td>completed</td>
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<tr>
<td>05124</td>
<td>2006</td>
<td>W. A. Peters</td>
<td>Neutron-dripline studies with direct fragmentation</td>
<td>[41]</td>
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<tr>
<td>07503</td>
<td>2007</td>
<td>W. A. Peters</td>
<td>Measurement of MoNA’s Efficiency</td>
<td>[21]</td>
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<tr>
<td>06025</td>
<td>2008</td>
<td>T. Baumann</td>
<td>Di-neutron decay of $^{16}$Be</td>
<td>[42–47]</td>
</tr>
<tr>
<td>08016</td>
<td>2008</td>
<td>A. Spyrou</td>
<td>Ground State of Neutron-Unbound $^{24}$N</td>
<td>Insufficient statistics</td>
</tr>
<tr>
<td>08026</td>
<td>2008</td>
<td>A. Schiller</td>
<td>Two-Neutron Decay from the ground state of $^{26}$O</td>
<td>[48–50]</td>
</tr>
<tr>
<td>07039</td>
<td>2009</td>
<td>P. DeYoung</td>
<td>Ground-State Neutron Decay of $^{21}$C</td>
<td>[51, 52]</td>
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<tr>
<td>09040</td>
<td>2010</td>
<td>N. Frank</td>
<td>Study of Neutron Unbound States in $^{28}$F</td>
<td>[53–55]</td>
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<tr>
<td>09069</td>
<td>2010</td>
<td>M. Mosby</td>
<td>Excitation Energy of Neon Prefragments</td>
<td>[56]</td>
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<tr>
<td>09067</td>
<td>2010</td>
<td>P. DeYoung</td>
<td>$^{13}$Be Ground State Formed via a (d,p) Reaction</td>
<td>[57, 58]</td>
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<tr>
<td>09028</td>
<td>2010</td>
<td>A. Schiller</td>
<td>$^{20}$O Neutron Knockout to $^{23}$O Excited States</td>
<td>analysis in progress</td>
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<td>10023</td>
<td>2011</td>
<td>W. Rogers</td>
<td>Unbound States in Neutron-Rich Oxygen Isotopes</td>
<td>analysis in progress</td>
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<tr>
<td>10007</td>
<td>2012</td>
<td>J. Smith</td>
<td>Two-neutron decay of $^{11}$Li</td>
<td>[59]</td>
</tr>
<tr>
<td>11027</td>
<td>2013</td>
<td>W. A. Peters</td>
<td>(d,n) studies using MoNA-LISA and VANDLE</td>
<td>analysis in progress</td>
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<tr>
<td>11028</td>
<td>2014</td>
<td>D. Bazin</td>
<td>Knockout reactions on $p$-shell nuclei</td>
<td>analysis in progress</td>
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<tr>
<td>12004</td>
<td>2014</td>
<td>N. Frank</td>
<td>Determination of the energy gap between the $sd – pf$ neutron shells in $^{23}$O</td>
<td>analysis in progress</td>
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<tr>
<td>12011</td>
<td>2014</td>
<td>Z. Kohley</td>
<td>Exploring the Equation of State with RIBs</td>
<td>analysis in progress</td>
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<tr>
<td>14014</td>
<td>–</td>
<td>A. Kuchera</td>
<td>Understanding two-nucleon unbound systems</td>
<td>Approved</td>
</tr>
<tr>
<td>15091</td>
<td>–</td>
<td>P. DeYoung</td>
<td>Measurement of $^9$He ground and excited states</td>
<td>Approved</td>
</tr>
<tr>
<td>15118</td>
<td>–</td>
<td>N. Frank</td>
<td>Lifetime measurements with the decay-in-target method</td>
<td>Approved</td>
</tr>
</tbody>
</table>
## 7 People

### MoNA undergraduate students

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Type</th>
<th>Year</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melanie Evanger</td>
<td>Concordia</td>
<td>all year</td>
<td>2001–2002</td>
<td>Master’s from Indiana Bloomington; Senior Engineer at BAE Systems</td>
</tr>
<tr>
<td>Maria-Teresa Herd</td>
<td>Bryn Mawr</td>
<td>MSU REU</td>
<td>2001–2002</td>
<td>Assistant Professor of Physics, Earlham College</td>
</tr>
<tr>
<td>Mustafa Rajabali</td>
<td>Concordia</td>
<td>all year</td>
<td>2001–2002</td>
<td>PhD in nuclear physics from Tennessee, Assistant Professor at Tennessee Tech</td>
</tr>
<tr>
<td>Ramsey Turner</td>
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<td>2001–2002</td>
<td>Master’s in Engineering from UMinnesota, IT analyst at Waldorf College</td>
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<td>Paul Yeager</td>
<td>NSCL</td>
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<td>2001–2002</td>
<td>pursued career as opera singer</td>
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<td>Joseph Bychowski</td>
<td>Hope</td>
<td>summer</td>
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<td>Jim Evans</td>
<td>IUSB</td>
<td>summer</td>
<td>2002–2003</td>
<td>Engineering Manager, Mobile Climate Control, Goshen IN</td>
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<td>Tony Grant</td>
<td>Millikin</td>
<td>summer</td>
<td>2002–2003</td>
<td>Instructor at ITT Technical Institute, Lincoln IL</td>
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<td>Yao Lu</td>
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<td>Erik Strahler</td>
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<td>all year</td>
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<td>Business Intelligence Developer at Epic Systems</td>
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<td>Peter VanWylen</td>
<td>Hope</td>
<td>summer</td>
<td>2002–2003</td>
<td>Research Director at Memphis Teacher Residency</td>
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<td>Sarah Clark</td>
<td>Westmont</td>
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<td>Kevin Daum</td>
<td>Central Michigan</td>
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<td>Eric Johnson</td>
<td>NE Wesleyan</td>
<td>summer</td>
<td>2003–2004</td>
<td>PhD in nuclear physics from Florida State, Deputy Director of Life and Health Actuarial at Florida Office of Insurance Regulation</td>
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<td>Draik Hecksel</td>
<td>Wabash</td>
<td>summer</td>
<td>2004–2005</td>
<td>M.S. from Purdue, Medical Physicist at Cadence Health</td>
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<td>Utsab Khadka</td>
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<td>Abe Pena</td>
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<td>Hope REU</td>
<td>2004–2005</td>
<td>Labview Automation Consultant at Photoprotective Technologies</td>
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<td>Robert Pepin</td>
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<td>MSU REU</td>
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<td>Graduate Student at the University of Washington</td>
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<td>Tina Pike</td>
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<td>Hope</td>
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<td>Marquette</td>
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<td>Daniel Albertson</td>
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<td>2006–2007</td>
<td>U. Chicago Master’s in Divinity, Global Studies Coordinator at Concordia College</td>
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<td>Math teacher at Ben Lippen School in Columbia, SC</td>
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<td>Deb Denby</td>
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<td>Malinda Reese</td>
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<td>Lucas Wagner</td>
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<td>Tova Yoast-Hull</td>
<td>Kenyon</td>
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<td>2006–2007</td>
<td>Graduate student in physics at University of Wisconsin</td>
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<td>Robert Jensen</td>
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<td>Chris Olsen</td>
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<td>all year</td>
<td>2007–2008</td>
<td>Graduate student in statistics at North Dakota State</td>
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<td>John Novak</td>
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<td>summer</td>
<td>2008–2009</td>
<td>Communications Specialist at American Physical Society</td>
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<td>Rob Anthony</td>
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<td>summer</td>
<td>2009–2010</td>
<td>Graduate student in Geoscience at Colorado State University</td>
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<td>Steven Ash</td>
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<td>Alegra Aulie</td>
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<td>2009–2010</td>
<td>Junior test engineer intern, Aurrion</td>
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<td>Nicholas Badger</td>
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<td>Ben Foster</td>
<td>Wabash</td>
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<td>Math and science high school teacher</td>
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<td>Zach Torstrick</td>
<td>IUSB</td>
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<td>Software engineer at IU Bloomington</td>
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<td>Magdalene McArthur</td>
<td>Howard University</td>
<td>summer</td>
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<td>Ed. intern at Howard Univ. Middle School for Math. and Science</td>
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<td>Fullerton College</td>
<td>OWU REU</td>
<td>2011–2012</td>
<td>Web designer, LA</td>
</tr>
<tr>
<td>Nathan Smith</td>
<td>Augustana</td>
<td>all year</td>
<td>2011–2012</td>
<td>Graduate student in applied physics at Northern Arizona Univ.</td>
</tr>
<tr>
<td>Kyle Williams</td>
<td>Augustana</td>
<td>all year</td>
<td>2011–2012</td>
<td>Pre-sales engineer at Insight Enterprise</td>
</tr>
<tr>
<td>Alicia Palmisano</td>
<td>Gettysburg</td>
<td>all year</td>
<td>2011–2014</td>
<td>Graduate student in physics at MSU</td>
</tr>
<tr>
<td>David Thompson</td>
<td>Gettysburg</td>
<td>all year</td>
<td>2012–2014</td>
<td>Graduate student in engineering, Carnegie Mellon</td>
</tr>
<tr>
<td>Kevin Krautbauer</td>
<td>Concordia</td>
<td>summer</td>
<td>2011–2012</td>
<td>Direct Service Professional at Care for Reaching Independence</td>
</tr>
<tr>
<td>Sierra Garrett</td>
<td>Westmont College</td>
<td>all year</td>
<td>2012–2013</td>
<td>Assoc. lab director, Westmont College</td>
</tr>
<tr>
<td>Alyson Barker</td>
<td>Westmont College</td>
<td>all year</td>
<td>2012–2013</td>
<td>Class of 2015</td>
</tr>
<tr>
<td>Nathaniel Taylor</td>
<td>Westmont College</td>
<td>all year</td>
<td>2012–2013</td>
<td>Class of 2015</td>
</tr>
<tr>
<td>Bethany Sutherland</td>
<td>Westmont College</td>
<td>all year</td>
<td>2011–2012</td>
<td>Engineering Administrator, Santa Barbara Imaging Systems</td>
</tr>
<tr>
<td>Jackson Kwiatkowski</td>
<td>Westmont College</td>
<td>all year</td>
<td>2011–2012</td>
<td>Project Manager at Rapid Product Solutions</td>
</tr>
<tr>
<td>Abdul Merhi</td>
<td>Augustana</td>
<td>all year</td>
<td>2012–2013</td>
<td>Graduate student in engineering at Iowa State</td>
</tr>
<tr>
<td>Franz Utermohlen</td>
<td>Gettysburg College</td>
<td>summer</td>
<td>2013–2014</td>
<td>Graduate student, nuclear theory, Ohio State</td>
</tr>
<tr>
<td>Andrew Lulis</td>
<td>Augustana</td>
<td>all year</td>
<td>2012–2013</td>
<td>physics major, Ohio State (transfer)</td>
</tr>
<tr>
<td>Zach Ingbretson</td>
<td>Concordia</td>
<td>all year</td>
<td>2012–2013</td>
<td>Class of 2014</td>
</tr>
<tr>
<td>Glenn Patterson</td>
<td>Wabash</td>
<td>summer</td>
<td>2012–2013</td>
<td>Class of 2014</td>
</tr>
<tr>
<td>Jaclyn Brett</td>
<td>Hope College</td>
<td>summer</td>
<td>2012–2013</td>
<td>Class of 2016</td>
</tr>
<tr>
<td>Braden Marks</td>
<td>Hope College</td>
<td>summer</td>
<td>2012–2013</td>
<td>Class of 2016</td>
</tr>
<tr>
<td>Mark Klehfoth</td>
<td>IUSB</td>
<td>summer</td>
<td>2010–2011</td>
<td>Graduate student in physics at University of Chicago</td>
</tr>
<tr>
<td>Richard Adam Bryce</td>
<td>Central Michigan</td>
<td>all year</td>
<td>2014–2016</td>
<td>Graduate student at Central Michigan University</td>
</tr>
<tr>
<td>Joseph Bullaro</td>
<td>Augustana</td>
<td>summer</td>
<td>2014–2015</td>
<td>Class of 2015</td>
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<tr>
<td>Heather Garland</td>
<td>Gettysburg</td>
<td>summer</td>
<td>2014–2015</td>
<td>Class of 2017</td>
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<tr>
<td>Rachel Parkhurst</td>
<td>Westmont College</td>
<td>summer</td>
<td>2014–2016</td>
<td>Class of 2016</td>
</tr>
<tr>
<td>David Hicks</td>
<td>Central Michigan</td>
<td>all year</td>
<td>2013–2014</td>
<td>Graduate student in computational physics at Duke University</td>
</tr>
<tr>
<td>Eli McDonald</td>
<td>Augustana</td>
<td>summer</td>
<td>2014–2015</td>
<td>applied biology, Vanderbilt (transfer)</td>
</tr>
<tr>
<td>Andy Dong</td>
<td>Wabash College</td>
<td>summer</td>
<td>2014–2015</td>
<td>Class of 2017</td>
</tr>
<tr>
<td>Inbum Lee</td>
<td>Wabash College</td>
<td>summer</td>
<td>2014–2015</td>
<td>Class of 2016</td>
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<tr>
<td>Elizabeth Havens</td>
<td>Central Michigan</td>
<td>all year</td>
<td>2014–2016</td>
<td>Class of 2017</td>
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<tr>
<td>Sam Wilensky</td>
<td>Gettysburg College</td>
<td>summer</td>
<td>2014–2016</td>
<td>Class of 2017</td>
</tr>
<tr>
<td>Tim Riley</td>
<td>Wabash College</td>
<td>summer</td>
<td>2015–2016</td>
<td>Class of 2017</td>
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# MoNA Graduate Students

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Start</th>
<th>Graduated</th>
<th>Experiment</th>
<th>Project/Title of Thesis</th>
<th>Current Position</th>
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<tbody>
<tr>
<td>Nathan Frank</td>
<td>MSU</td>
<td>2000</td>
<td>2006</td>
<td>03033</td>
<td>Spectroscopy of neutron unbound states in neutron rich oxygen isotopes</td>
<td>Assistant Professor, Augustana College, East Moline, IL</td>
</tr>
<tr>
<td>William Peters</td>
<td>MSU</td>
<td>1999</td>
<td>2007</td>
<td>03048</td>
<td>Commissioning and first results from MoNA</td>
<td>Research Scientist, ORNL, TN</td>
</tr>
<tr>
<td>Calem Hoffman</td>
<td>FSU</td>
<td>2004</td>
<td>2009</td>
<td>05039</td>
<td>Investigation of the neutron-rich oxygen isotopes at the dripline</td>
<td>Assistant Physicist, ANL, IL</td>
</tr>
<tr>
<td>Greg Christian</td>
<td>MSU</td>
<td>2006</td>
<td>2011 (M.S.)</td>
<td>05124</td>
<td>Production of unbound nuclei via fragmentation</td>
<td>Assistant Professor, Texas A&amp;M, College Station, TX</td>
</tr>
<tr>
<td>Michael Strongman</td>
<td>MSU</td>
<td>2006</td>
<td>2011 (M.S.)</td>
<td>08016</td>
<td>Neutron spectroscopy of $^{22}$N and the disappearance of the $N = 14$ shell</td>
<td>Patrick Air Force Base, FL</td>
</tr>
<tr>
<td>Shea Mosby</td>
<td>MSU</td>
<td>2007</td>
<td>2011</td>
<td>07039</td>
<td>Spectroscopy of neutron unbound states in neutron rich carbon $^{15}$Be via (d,p)</td>
<td>Staff Scientist, LANL, NM</td>
</tr>
<tr>
<td>Jesse Snyder</td>
<td>MSU</td>
<td>2008</td>
<td>2013</td>
<td>09067</td>
<td>Two-neutron decay of $^{11}$Li</td>
<td>Postdoc in Medical Physics, University of Iowa</td>
</tr>
<tr>
<td>Jenna Smith</td>
<td>MSU</td>
<td>2009</td>
<td>2014</td>
<td>10007</td>
<td></td>
<td>Postdoc, TRIUMF, Vancouver, Canada</td>
</tr>
<tr>
<td>Michael Jones</td>
<td>MSU</td>
<td>2011</td>
<td></td>
<td>12004</td>
<td></td>
<td></td>
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<tr>
<td>Krystin Stiefel</td>
<td>MSU</td>
<td>2012</td>
<td></td>
<td>12011</td>
<td>$^{24}$O (d,p)</td>
<td></td>
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<tr>
<td>Thomas Redpath</td>
<td>MSU</td>
<td>2014</td>
<td></td>
<td></td>
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<tr>
<td>Han Liu</td>
<td>MSU</td>
<td>2014</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Daniel Votaw</td>
<td>MSU</td>
<td>2015</td>
<td></td>
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# Other Graduate Students

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Start</th>
<th>Graduated</th>
<th>Experiment</th>
<th>Project/Title of Thesis</th>
<th>Current Position</th>
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</thead>
<tbody>
<tr>
<td>Rudolf Izsak</td>
<td>Budapest</td>
<td>2005</td>
<td>2013</td>
<td>03038</td>
<td>Coulomb-breakup of neutron-rich nuclei</td>
<td>Electronic and Computer Engineering, Brunel University, London</td>
</tr>
<tr>
<td>Michelle Mosby</td>
<td>MSU</td>
<td>2007</td>
<td>2014</td>
<td>09069</td>
<td>Excitation energy of neon prefragments</td>
<td>Postdoc, LANL, NM</td>
</tr>
<tr>
<td>Harsha Attanayake</td>
<td>OU</td>
<td>2008</td>
<td>2014</td>
<td>08026</td>
<td>Two-neutron decay from the ground state of $^{26}$O</td>
<td>Engineering company in Columbus, OH</td>
</tr>
<tr>
<td>Dilupama Divaratne</td>
<td>OU</td>
<td>2008</td>
<td>2013</td>
<td>09028</td>
<td>$^{24}$O neutron knockout to $^{23}$O excited states</td>
<td>Visiting Assistant Professor, Miami University, OH</td>
</tr>
<tr>
<td>Jessica Freeman</td>
<td>Hampton</td>
<td>2013</td>
<td></td>
<td></td>
<td>Segmented target</td>
<td></td>
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<tr>
<td>Adeleke Adeyemi</td>
<td>Hampton</td>
<td>2014</td>
<td></td>
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MoNA Post-Doctoral Researchers

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<thead>
<tr>
<th>Name</th>
<th>Dates</th>
<th>Current Position</th>
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<tbody>
<tr>
<td>Jean-Luc Lecouey</td>
<td>2003-2005</td>
<td>Staff Physicist, LPC Caen, France</td>
</tr>
<tr>
<td>Ken Yoneda</td>
<td>2003-2005</td>
<td>Laboratory Head, RIKEN, Japan</td>
</tr>
<tr>
<td>Andreas Schiller</td>
<td>2003-2007</td>
<td>Research Scientist, Norwegian Defence Research Establishment, Oslo, Norway</td>
</tr>
<tr>
<td>Heiko Scheit</td>
<td>2006</td>
<td>Research Scientist, GSI, Germany</td>
</tr>
<tr>
<td>Artemis Spyrou</td>
<td>2007-2009</td>
<td>Assistant Professor, Michigan State University, East Lansing, MI</td>
</tr>
<tr>
<td>Zachary Kohley</td>
<td>2011-2012</td>
<td>Kohley’s Superior Water &amp; Propane, Muskegon, MI</td>
</tr>
<tr>
<td>Anthony Kuchera</td>
<td>2014-present</td>
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MoNA collaboration directors

<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Institution</th>
</tr>
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<tbody>
<tr>
<td>2001–2002</td>
<td>Bryan A. Luther</td>
<td>Concordia College</td>
</tr>
<tr>
<td>2002–2003</td>
<td>Thomas Baumann</td>
<td>Michigan State University</td>
</tr>
<tr>
<td>2003–2004</td>
<td>Joseph E. Finck</td>
<td>Central Michigan University</td>
</tr>
<tr>
<td>2004–2005</td>
<td>Paul A. DeYoung</td>
<td>Hope College</td>
</tr>
<tr>
<td>2005–2006</td>
<td>James A. Brown</td>
<td>Wabash College</td>
</tr>
<tr>
<td>2006–2007</td>
<td>Jerry D. Hinnefeld</td>
<td>Indiana University at South Bend</td>
</tr>
<tr>
<td>2007–2008</td>
<td>Warren F. Rogers</td>
<td>Westmont College</td>
</tr>
<tr>
<td>2008–2009</td>
<td>Paul A. DeYoung</td>
<td>Hope College</td>
</tr>
<tr>
<td>2009–2010</td>
<td>Bryan A. Luther</td>
<td>Concordia College</td>
</tr>
<tr>
<td>2010–2011</td>
<td>Deseree Meyer</td>
<td>Rhodes College</td>
</tr>
<tr>
<td>2011–2012</td>
<td>Nathan Frank</td>
<td>Augustana College</td>
</tr>
<tr>
<td>2012–2013</td>
<td>Robert Haring-Kaye</td>
<td>Ohio Wesleyan University</td>
</tr>
<tr>
<td>2013–2014</td>
<td>Sharon Stephenson</td>
<td>Gettysburg College</td>
</tr>
<tr>
<td>2014–2015</td>
<td>Warren Rogers</td>
<td>Westmont College</td>
</tr>
<tr>
<td>2015–2016</td>
<td>James A. Brown</td>
<td>Wabash College</td>
</tr>
</tbody>
</table>

Awards


Faculty grants

1. RUI: Radioactive nuclear beam physics with undergraduates at Hope College
   Paul A. DeYoung and Graham F. Peaslee
   NSF 0098061, 06/01/2001–05/31/2005

2. MRI: Construction of one layer of a highly efficient neutron detector to study neutron-rich rare isotopes at the NSCL (Hope College)
   Paul A. DeYoung and Graham F. Peaslee
   NSF 0132405, 09/01/2001–12/31/2004

3. MRI: Construction of one layer of a highly efficient neutron detector to study neutron-rich rare isotopes at the NSCL
   Joseph Finck
   NSF 01323532, 09/01/2001–08/31/2004

4. MRI: High efficiency neutron detector layer
   James Brown
   NSF 0132507, 0432042, 09/01/2001–08/31/2004
5. MRI: Construction of a Layer of a Highly Efficient Neutron Detection Wall for NSCL (IUSB)
   Jerry Hinnefeld
   NSF 0132567, 09/01/2001–08/31/2004

6. MRI: Fabrication of One Layer of a High-Efficiency Neutron Detector
   Ruth Howes
   NSF 0132367, 09/01/2001–08/31/2004

7. MRI: Constructing a Layer for the Large Neutron Detector at NSCL
   Paul Pancella
   NSF 0132438, 09/01/2001–08/31/2004

8. MRI: A Highly Efficient Neutron Detector Array to Study Neutron-Rich Rare Isotopes at the NSCL
   Bryan Luther
   NSF 0132725, 09/01/2001–08/31/2004

9. MRI: Large high-efficiency neutron array detector at MSU
   Warren Rogers
   NSF 0132641, 09/01/2001–08/31/2003

10. RUI: Multifaceted opportunities in nuclear physics for undergraduates at Hope College
    Paul A. DeYoung and Graham F. Peaslee
    NSF 0354920, 05/15/2004–04/30/2008

11. Nuclear physics research at Westmont College
    Warren Rogers
    NSF 0502010, 06/01/2005–05/31/2010

12. An RUI proposal to investigate the neutron drip line using the Modular Neutron Array
    Joseph Finck
    NSF 0555439, 07/15/2006–06/30/2009

13. RUI: Using MoNA, exploring neutron unbound states in nuclei near and beyond the neutron dripline
    James Brown
    NSF 0555488, 07/01/2006–06/30/2010

14. RUI: Fundamental and applied nuclear physics with undergraduates
    Paul A. DeYoung and Graham F. Peaslee
    NSF 0651627, 05/15/2007–04/30/2011

15. RUI: Studying exotic nuclei with the Modular Neutron Array (MoNA)
    Joseph Finck
    NSF 0855456, 09/01/2009–08/31/2012

16. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of
    exotic nuclei
    Bryan Luther NSF 0922559, 10/01/2009–09/30/2012

17. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of
    exotic nuclei
    Robert Kaye
    NSF 0922409, 10/01/2009–09/30/2012

18. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of
    exotic nuclei
    Deseree Meyer
    NSF 0922473, 10/01/2009–09/30/2012

19. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of
    exotic nuclei
    Sharon Stephenson
    NSF 0922335, 10/01/2009–09/30/2012
20. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of exotic nuclei
   James Brown
   NSF 0922446, 10/01/2009–09/30/2012

21. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of exotic nuclei
   Jerry Hinnefeld
   NSF 0922537, 10/01/2009–09/30/2012

22. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of exotic nuclei
   Joseph Finck
   NSF 0922462, 10/01/2009–09/30/2012

23. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of exotic nuclei
   Warren Rogers
   NSF 0922622, 10/01/2009–09/30/2012

24. MRI-Consortium: Development of a neutron detector array by undergraduate research students for studies of exotic nuclei
   Paul A. DeYoung and Graham F. Peaslee
   NSF 0922794, 10/01/2009–09/30/2012

25. RUI: Studies of unstable neutron-rich nuclei and interdisciplinary applications of nuclear physics with undergraduates
   Paul A. DeYoung
   NSF 0969058, 05/15/2010–04/30/2013

26. RUI: Establishing an Undergraduate Research Group in Nuclear Physics
   Nathan Frank
   NSF 0969173, 09/15/2010–08/31/2014

27. RUI: Study of light exotic nuclei near the neutron dripline
   Warren Rogers
   NSF 1101745, 05/15/2011–05/14/2014

28. RUI: Studies of exotic nuclei with the MoNA LISA neutron detectors
   Joseph Finck
   NSF 1205357, 06/01/2012–05/31/2016

29. RUI: Neutron physics from $^4$He to the edge of the dripline
   Sharon Stephenson
   NSF 1205537, 10/1/2012–09/30/2015

30. RUI: Cutting-Edge Nuclear Physics Research (Collaborative and Interdisciplinary) at Hope College
   Paul A. DeYoung
   NSF 1306074, 06/15/2013–05/31/2016

31. Active target development for the study of neutron-unbound nuclei
   P. Gueye, M. Thoennessen, and N. Frank
   NSSC-MSI Research Grant Award, NNSA, 1/1/2013–12/31/2015

32. RUI: Undergraduate Research on Neutron-Rich Nuclei
   Nathan Frank
   NSF 1404236, 08/1/2014–07/31/2017

33. RUI: Study of Exotic Neutron-Rich Nuclei at Westmont College and NSCL,MSU
   Warren Rogers
   NSF 1506402, 07/15/2015–07/14/2018
References


[18] Nuclear science and security consortium. [http://nssc.berkeley.edu](http://nssc.berkeley.edu)


