

NSCL PAC 36 – 2. Description of Experiment

TITLE: IAS to IAS 2p decay and test of charge independence from an IMME fit to A=16.

By submitting this proposal, the spokesperson certifies that all collaborators listed have read the proposal and have agreed to participate in the experiment.

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OTHER EXPERIMENTERS: (Please spell out first name and indicate Graduate Students (GS), Undergraduate students (UG) and Postdoctoral Associates (PD); include a separate sheet if necessary)

Last name, First name	Organization	Last name, First name	Organization
Shane, Rebecca	WU(GS) /MSU – (PD)	Lynch, Bill	MSU
Mastren, Tara	WU(GS)	Tsang, Betty	MSU
Manfredi, Juan	WU(UG)	Chajeki, Zbigniew	MSU
Jager, Marieke	WU(UG)	Youngs, Michael	MSU
Wuosmaa, Alan	WMU	Coupland, Daniel	MSU
Shore, Aimee/ Baugher, Travis	WMU	Gade, Alaxander	MSU
Winkelbauer, Jack	MSU	Weisshaar, Dirk	MSU

REQUEST FOR PRIMARY BEAM SEQUENCE INCLUDING TUNING, TEST RUNS, AND IN-BEAM CALIBRATIONS: (Summary of information provided on Beam Request Worksheet(s). Make separate entries for repeat occurrences of the same primary beam arising from user-requested interruptions to the experiment.)

	Isotope	Energy (MeV/nucleon)	Minimum Intensity (particle-nanoampere)	Sum of Beam Preparation Times (Hours)	Sum of Beam-On-Target Times (Hours)
Beam 1	20Ne	170	50	12+5=17	12+48 = 60
Beam 2					
Beam 3					
Beam 4					

ADDITIONAL TIME REQUIREMENTS THAT REQUIRE USE OF THE CCF (e.g. modification of the A1900 standard configuration, development of optics, ... Obtain estimates from the [A1900 Device Contact](#).)

Additional CCF use time

Total Hours:

Andreas Stolz says 170 MeV/A and 75 na should be used for planning purposes.

TOTAL TIME REQUEST (HOURS): **77**
 (Calculated as per item 4. of the Notes
 for
 PAC 36 in the [Call for Proposals](#))

Access to:	Experimental Vault	SET UP TIME (before start of beam)	TAKE DOWN TIME
	Electronics Set-up Area	<u> 14 </u> days	<u> 7 </u> days
	Data Acquisition Computer	<u> 14 </u> days	<u> 7 </u> days

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HOURS APPROVED: _____

HOURS RESERVED: _____

WHEN WILL YOUR EXPERIMENT BE READY TO RUN? ___8___ / ___1___ / ___11___

EXPERIMENTAL LOCATION:

<input type="checkbox"/> Transfer Hall (in the A1900)	<input type="checkbox"/> Transfer Hall (downstream of the A1900)
<input type="checkbox"/> N2 vault	<input type="checkbox"/> N2 vault (with Sweeper line)
<input type="checkbox"/> S2 vault (Irradiation line)	<input checked="" type="checkbox"/> S2 vault
<input type="checkbox"/> S3 vault	

EXPERIMENTAL EQUIPMENT:

<input type="checkbox"/> A1900	<input type="checkbox"/> Beta Counting System	<input type="checkbox"/> Beta-NMR Apparatus
<input type="checkbox"/> Sweeper Magnet	<input type="checkbox"/> Neutron Walls	<input type="checkbox"/> LENDA
<input type="checkbox"/> Modular Neutron Array	<input type="checkbox"/> Neutron Emission Ratio Observer	
<input checked="" type="checkbox"/> High Resolution Array	<input checked="" type="checkbox"/> 53" Chamber	<input checked="" type="checkbox"/> CsI(Na) Scintillator Array
<input type="checkbox"/> Segmented Ge Array: [] classic; [] mini; [] beta; [] delta; [] barrel; [] other		
<input type="checkbox"/> GRETINA		
<input type="checkbox"/> S800 Spectrograph: [] with; [] without scattering chamber	<input type="checkbox"/> DDAS	
<input type="checkbox"/> Radio Frequency Fragment Separator	<input type="checkbox"/> LEBIT	<input type="checkbox"/> BECOLA
		<input type="checkbox"/> Other (give details)

DETAIL ANY MODIFICATION TO THE STANDARD CONFIGURATION OF THE DEVICE USED, OR CHECK NONE: [] NONE

DETAIL ANY REQUIREMENTS THAT ARE OUTSIDE THE CURRENT NSCL OPERATING ENVELOPE, OR CHECK NONE (Examples: vault reconfiguration, new primary beam, primary beam intensities above what is presently offered, special optics, operation at unusually high or low rigidities): [] NONE

²⁰Ne primary beam

REACTION TARGETS AT EXPERIMENTAL STATION:

Be target

LIST ALL RESOURCES THAT YOU REQUEST THE NSCL TO PROVIDE FOR YOUR EXPERIMENT BEYOND THE STANDARD RESOURCES OUTLINED IN ITEM 12 OF THE NOTES FOR PAC 36 IN THE CALL FOR PROPOSALS. [] NONE

**A few days of Craig Snow's time to design a mount for 1/2 of CAESER.
(All hardware can be built at WU.)**

LIST ANY BREAKS REQUIRED IN THE SCHEDULE YOUR EXPERIMENT, OR CHECK NONE: (Examples of why an experiment might need an interruption: to change the experimental configuration; to complete the design of an experimental component based on an initial measurement.) [] NONE

See below

OTHER SPECIAL REQUIREMENTS: (Safety related items are listed separately on following pages.) [] NONE

We are not asking for any calibration time as we propose to do this experiment before dismantling the set-up for exp. #10001 that was approved for 129 hrs in the last (35) PAC. (That is, the time for the full complement of calibrations need for A = 16 as well as A = 8 has already been provided (in the 10001, PAC 35 request.)

Required SUMMARY (no more than 200 words):

We propose to measure the two-proton decays of two analog T=2 states; $^{16}\text{Ne}_{g.s.} \rightarrow 2p + ^{14}\text{O}_{g.s.}$ and $^{16}\text{F}_{IAS} \rightarrow 2p + ^{14}\text{N}_{IAS}$. We will study the correlations between the decay fragments and compare them to theoretical predictions. From the invariant masses of the decay products, we will determine the masses of $^{16}\text{Ne}_{g.s.}$ and $^{16}\text{F}_{IAS}$ and thus complete the A=16 quintet. We will fit the quintet masses with the isobaric multiplet mass equation (IMME) and look for isospin breaking effects. If this experiment is done without breaking down the apparatus from exp #10001, this project can be done with *only 77 additional hrs of PAC 36 approved time.*

Description of Experiment

I. Physics Justification

In our previous continuum-decay spectroscopy study (#08001, done in January 2010) we found that:

- a) the ${}^8\text{C}$ ground state decays via two sequential steps of prompt two-proton ($2p$) decay (through the ${}^6\text{Be}_{\text{gs}}$ intermediate state),
- b) The first $2p$ decay in this sequence has an enhanced “diproton” character, and
- c) That the analog of ${}^8\text{C}$ in ${}^8\text{B}$ (${}^8\text{B}_{\text{IAS}}$) also undergoes $2p$ decay (this being the first case of IAS to IAS $2p$ decay), see Fig. 1. In addition to the information on $2p$ decay, we obtained (among other findings) a new mass for ${}^8\text{C}_{\text{g.s.}}$ (a fact relevant to this proposal) and found a new state in ${}^{10}\text{C}$ that provides an example of four-body decay. A short paper on the $2p$ work was published last year [1] and a comprehensive long paper was submitted recently [2].

From the last PAC we were approved (proposal # 10001) to study the $2p$ correlations from the ${}^8\text{B}_{\text{IAS}} \rightarrow {}^6\text{Li}_{\text{IAS}} + 2p$ decay and to detect the 3.5 MeV gamma ray from the deexcitation of ${}^6\text{Li}_{\text{IAS}}$ (see Fig. 1a). The present proposal uses the same apparatus that will be used for experiment #10001 to study the $2p$ decays of ${}^{16}\text{Ne}_{\text{g.s.}}$ and ${}^{16}\text{F}_{\text{IAS}}$ (see Fig. 1b.) In this case, the energy of the ${}^{16}\text{F}_{\text{IAS}}$ is unknown (this is why there is a “?” in Fig. 1b for this level.) Thus the investigation of the $A = 16$ system not only provides the potential to find a second *pair* of analog $2p$ emitters but also, by reconstructing the energy of ${}^{16}\text{F}_{\text{IAS}}$, we can complete the $A=16$ quintet.

Complete correlations (energy and angular) in $2p$ decay of ground states have been measured for just ${}^6\text{Be}_{\text{g.s.}}$ and ${}^{45}\text{Fe}_{\text{g.s.}}$ decay [3,4]. The only known light $2p$ ground-state emitters are ${}^6\text{Be}_{\text{g.s.}}$, ${}^{12}\text{O}_{\text{g.s.}}$, ${}^{16}\text{Ne}_{\text{g.s.}}$ and these have methodological importance for understanding the phenomenon in general. Like ${}^6\text{Be}_{\text{g.s.}}$, ${}^{16}\text{Ne}_{\text{g.s.}}$ can theoretically undergo sequential $2p$ decay through the low-energy tail of its $1p$ daughter (Fig. 1a and 1b). But as found experimentally for ${}^6\text{Be}_{\text{g.s.}}$, ${}^{16}\text{Ne}_{\text{g.s.}}$ $2p$ decay is expected to be described by a prompt 3-body process [5]. Comparisons between ${}^6\text{Be}$ and ${}^{16}\text{Ne}$ are important as the Coulomb forces in the latter are 4 times larger and barrier penetration effects are more pronounced. Simultaneous reproduction of both ${}^6\text{Be}$ and ${}^{16}\text{Ne}$ decay correlations will thus provide an important test of 3-body decay models. Some information on ${}^{16}\text{Ne}$ decay correlations exists [6], however only the angular correlations were measured, statistics were low, and the separation of the ground-state from excited states was not complete. The proposed experiment will measure both the energy and angular correlations with higher statistics (~ 1000 events). The first excited state of ${}^{16}\text{Ne}$ is at 1.7 MeV and will clearly be separated from the ground state in our proposed experiment. These data will be compared to existing predictions [5].

${}^{16}\text{F}_{\text{IAS}}$ is also an interesting case of $2p$ decay in that the isospin allowed $1p$ intermediates are too high and narrow (in energy) to be relevant (Fig. 1b). Thus to the extent that isospin is conserved, it thus can be considered a Goldansky-type prompt $2p$ decay like ${}^{45}\text{Fe}$ [4]. Comparisons of ${}^{16}\text{Ne}_{\text{g.s.}}$ and ${}^{16}\text{F}_{\text{IAS}}$ correlations therefore should shed light on the influence of the intermediate state and possible isospin breaking effects. Also like ${}^8\text{B}_{\text{IAS}}$ decay, we would not be surprised to find weak isospin breaking transitions to the $1p$ intermediate ${}^{15}\text{O}$ (see [2].)

Again, as was the case in our prior study, where a new mass and width for ${}^8\text{C}$ were extracted, we expect to do the same for ${}^{16}\text{Ne}$. This is relevant in that Gregorenko et al. have suggested that the experimental width tabulated for ${}^{16}\text{Ne}$ (~ 122 keV) is incomprehensively too large [4]. Barker made the same general point [7]. We certainly can test this width, as from our previous work we know that our decay spectroscopy technique is capable of extracting a width (or upper limit to the width) to ~ 60 keV which is significantly below the present listed value of 122 keV.

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A consequence of obtaining the energy of $^{16}\text{F}_{\text{IAS}}$ (and a new measurement of the mass/width for ^{16}Ne) we will complete the T=2 quintet for A=16. Charge independence of the nuclear force can be tested by fitting this quintet to the Isobaric Multiplet Mass Equation (IMME) (Eq. 1). If the nucleon-nucleon interaction were charge independent, the masses of the 2T+1 members of the isobaric multiplet would only differ by the Coulomb interaction and the masses would be perfectly described by the IMME equation using the constant, linear and quadratic terms,

$$M = a + bT_z + cT_z^2 + (dT_z^3 + eT_z^4). \quad (1)$$

Finite “d” and “e” terms can arise from two general isospin breaking effects. The first is that the wave functions are not the same when protons and neutrons are exchanged. This can be due to a Thomas-Ehrman-like effect, i.e. an asymmetric effect of the continuum on the valence neutrons and protons wavefunctions. However isospin mixing can also require higher order terms. For example, 0^+ states of lower isospin in the inner members of a quintet can mix with these states shifting their energy. Mixing with a T=0 state, will give rise to an “e” term where mixing with T=1 states can also give a “d” term. We will also remeasure the mass of ^{16}Ne for which there are only two previous measurements with precision of 40 keV or less. (They literature values differ by 2σ .)

In the 1979 review of Benenson and Kashy [8], and even that of the more recent compilation done in 1998 [9], there is no strong evidence for isospin breaking in the IMME, except for the A = 9 quartet. However, our recent measurement of $^8\text{C}_{\text{g.s.}}$ gave a new value for its mass and allowed a new evaluation of the A=8 quintet. The isospin breaking term “d” was found to be nonzero at the 3σ level and similar in magnitude to that obtained for A=9 quartet. Isospin breaking effects have been recently observed by Triambak, Garcia and Adelberger et al. for A=32 [10], and we have reevaluated the A=36 case with the latest tabulated values of the masses and observed a small effect.

To test for finite “d” one needs to study quartets (T=3/2, odd A). To test for finite “d” and “e” coefficients one needs quintets. The status of the “d” coefficient as of 1979 is displayed in Fig. 2a, a figure from the Benenson and Kashy review. At that time, no compelling case could be made for a finite “d” term except for A=9. Known quintets are restricted to A = 4n nuclei as the $T_z = 0$, T = 2 states in 4n+2 nuclei are very high in excitation energy and difficult to separate from the larger density of T = 0 states.

We have reviewed (refit) the IMME quartets and quintets, using all the current data. The results are shown in Fig. 2b, where the large symbols are used for the quintets (for which both the d and e terms are fit) and small triangles for the quartets (only the d term beyond quadratic is fit.) One should note the scale is now finer than for Fig. 2a and the search can look for smaller deviations than was possible before. If one focuses on the cases with small error bars, there appears to be a trend of increasing values of “d” with decreasing A. (The case of A = 32 is interesting. The authors of recent work [9] claim a statistically significant negative value of d. We find that, while this is true without an “e” term, it is not when this term is included.)

The absence of data for A = 16 is conspicuous. As noted above, this is because the mass of $^{16}\text{F}_{\text{IAS}}$ is not known (the “?” in Figure 1b.) The reason why this state has escaped detection thus far is clear as, if this state were to decay by 2p emission, an experiment like the one we now propose is needed. Such an experiment could not have been done until recently. The systematics across A (i.e. like that presented in Fig. 2b) is needed to determine if isospin breaking is robust, if there is a trend with A, and to disentangle the two possible mechanisms. In addition the A = 16 quintet is predicted to have strong isospin breaking effects due to the much stronger s-wave character of the ^{16}Ne proton wavefunction compared to the ^{16}C neutron wavefunction [5].

II. Goals of the proposed experiment

We have four goals for this experiment.

1. To detect the 2p decays of *both* $^{16}\text{Ne}_{\text{gs}}$ and $^{16}\text{F}_{\text{IAS}}$ in high statistics (on the order of 1000 events.) These states will be formed in neutron and proton knockout reactions from the ^{17}Ne projectile. These will be only the second *pair* of analog 2p emitters found.
2. From the invariant mass of the detected decay products, we will measure the energy and width of these two states. If the theoretical estimates of the widths are correct, then we will only obtain upper limits of ~ 60 keV. On the other hand, if we confirm the previous value of 122 keV for ^{16}Ne , this will indicate that there are problems with the existing theories.
3. The correlations between the momenta of the decay products will be compared to the predictions of the cluster model calculations of Grigorenko et al.
4. The remeasurement of the mass of ^{16}Ne and the first measurement of the mass of $^{16}\text{F}_{\text{IAS}}$ will complete the quintet for $A = 16$. The masses of the ^{16}O , ^{16}N , and ^{16}C $T=2$ states are already known to 7 keV or better. We should measure the masses of ^{16}Ne and $^{16}\text{F}_{\text{IAS}}$ to an uncertainty of 30 keV. This should allow the extraction of “d” and “e” to an uncertainty of ~ 3 keV, similar to what we obtained for $A = 8$ quintet (see 2b). This will allow us to determine if the $A=16$ quintet, like the $A=8$ case, has a finite “d” coefficient, implying an isospin breaking mass effect of one type or another.

We emphasize that our previous work with the $A = 8$, accomplished all of these goals. The new parameters for the ground-state of ^8C can now largely be accounted for by an R-matrix calculation for “diproton” emission [2]. We have shown that the $T = 2$ analog of $^8\text{C}_{\text{gs}}$, $^8\text{B}_{\text{IAS}}$ also decays by 2p emission. The new values for $^8\text{C}_{\text{gs}}$ have allowed for a high precision test of the IMME equation from which we have found that an isospin breaking term *is* required. Approval of the presently requested time will allow us to determine if the $A = 16$ system also requires such a term. (In order to do this we need to determine the energy of the $^{16}\text{F}_{\text{IAS}}$ and reduce the uncertainty for the width of $^{16}\text{Ne}_{\text{gs}}$. Goals we know we can achieve using exactly the same procedure as used for the $A=8$ system.)

Experimental Details

The experiment apparatus is identical to the already approved 10001 experiment. The only differences between these experiments and our completed (and published) 8001 experiment are:

- a) The addition of a part of CEASAR to measure the ground-state M1 from the decay of the $T = 1$ IAS in the residue ($^{14}\text{N}_{\text{IAS}}$ in the present case) and
- b) Using external preamps (with much lower gain) for the two inner HiRA E detectors so that the residues ($^{14}\text{O}_{\text{gs}}$ and $^{14}\text{N}_{\text{IAS}}$) are within the range of our downstream pulse processing system.

The present request is for 2 days of beam time to collect the data on the $A = 16$ systems. Example simulations for the $^{16}\text{Ne} \rightarrow ^{14}\text{O} + 2\text{p}$ decay are shown on the lower panels of Fig. 4. For comparison we show the $A = 8$ case in the upper panels. For the $A=16$ case we will have to change the gains (by using external preamps) for the two detectors closest to the beam.) No time is requested for energy calibration of the CsI detectors, however it is our request that this experiment be done either back-to-back or without tearing down the approved 10001 experiment. We have added 12 hours of beam time to ensure that the rather complex system is up and

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running properly and that the extended range offered by the added external preamps is working properly. This request is based on our desire to acquire at least 1000 events for each $2p$ decay.

The primary beam (^{20}Ne) is not on the present beam list, however we have discussed this with the NSCL staff (Andreas Stoltz and Tom Ginter) and the parameters in the submitted LISE++ file are those that have been suggested to us.

References

1. R.J. Charity, J.M. Elson, J. Manfredi, R. Shane, L.G. Sobotka, Z. Chajecki, D. Coupland, T. Ghosh, H. Iwasaki, M. Kilburn, J. Lee, W.G. Lynch, A. Sanetullaev, M.B. Tsang, J. Winkelbauer, M. Youngs, S. Marley, D.V. Shetty, A.H. Wuosmaa, M. Howard, PRC 041304 (2010) and PRC submitted (2011).
2. R.J. Charity, J.M. Elson, J. Manfredi, R. Shane, L.G. Sobotka, Z. Chajecki, D. Coupland, T. Ghosh, H. Iwasaki, M. Kilburn, J. Lee, W.G. Lynch, A. Sanetullaev, M.B. Tsang, J. Winkelbauer, M. Youngs, S. Marley, D.V. Shetty, A.H. Wuosmaa, M. Howard, PRC submitted (2011), available from the NP archive or from the authors.
3. L.V. Grigorenko, M. V. Zhukov, T. D. Wiser, K. Mercurio, R. J. Charity, R. Shane, L. G. Sobotka, J. M. Elson, A. Wuosmaa, A. Banu, M. McCleskey, L. Trache, and R. E. Tribble, Phys. Rev. C 80, 034602 (2009).
4. L. V. Grigorenko, et al., Phys. Lett. B 677 30 (2009).
5. L. V. Grigorenko, et al., Phys. Rev. Lett. 88, 042502(2002).
6. I. Mukha et al., Phys. Rev. C 82 (2010) 054315.
7. F. C. Barker, Phys. Rev. C **59**, 535 (1999).
8. W. Benenson and E. Kashy, Rev. Mod. Phys. **51**, 527 (1979).
9. J. Britz, A. Pape, and M.S. Antony, Atomic Data and nuclear Data Tables **69**, 125 (1988).
10. S. Triambak, A. Garcia, E. G. Adelberger, et al, Phys. Rev. C. **73**, 054313 (2006). (Note this paper uses the high-energy definition of $T_z = [Z-N]/2$).

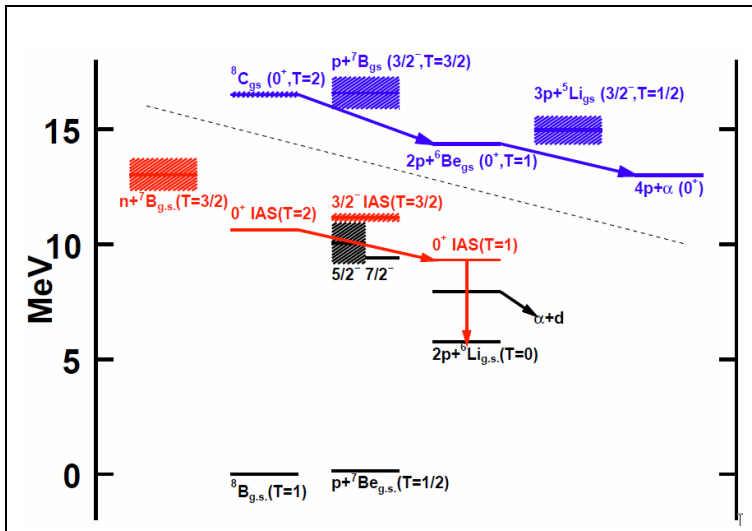


Fig. 1a: Decay schemes for $A=8$ $2p$ decay cases. Decay of ${}^8\text{C}$ has been shifted up the ordinate. The decays in color are isospin allowed. The decay indicated by the blue (top) arrows were already studied in detail in exp #8001, and the decays in red (bottom) were found in #8001 and will be studied in detail in exp #10001.

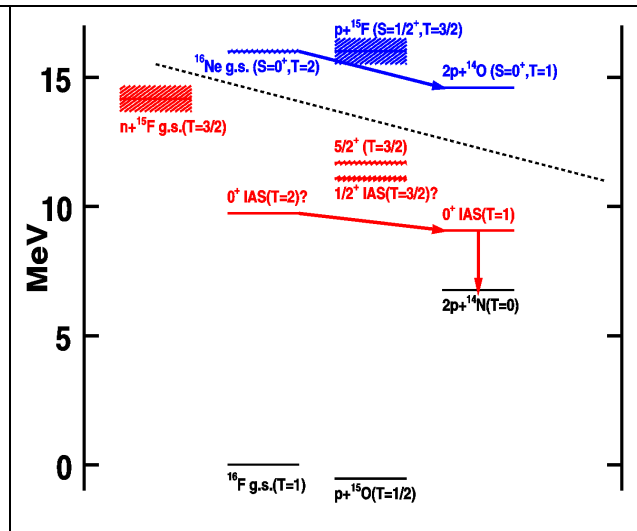


Fig. 1b: Decay schemes for $A=16$ suspected $2p$ decay cases. The decays (arrows) are isospin allowed and are the subject of the present proposal. Note that the energy of ${}^{16}\text{F}_{\text{IAS}}$ is *unknown*. (For this figure the energy is taken from the energy of the mirror level minus 200 keV, a procedure which gives the correct value for ${}^8\text{B}_{\text{IAS}}$.)

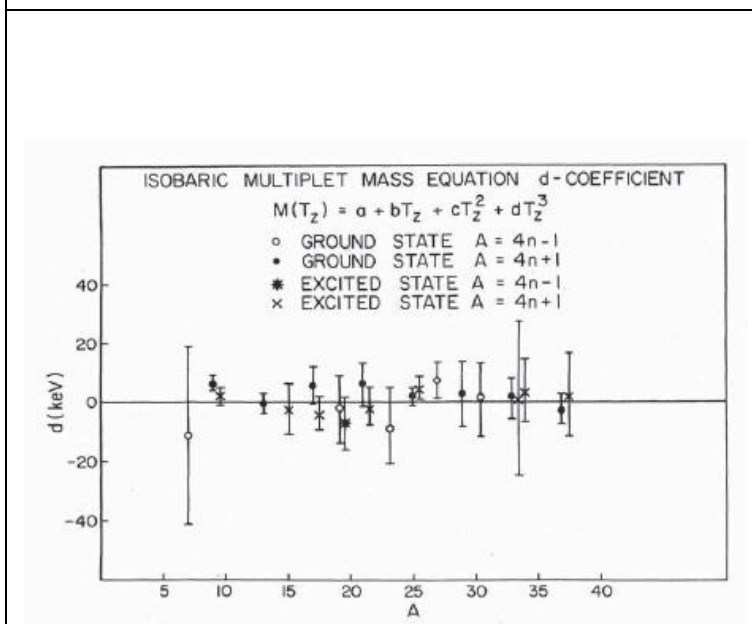


Fig. 2a: The d term of the IMME fit to quartets from Benenson and Kashy [9]. Note the large error bar on the $A=7$ case.

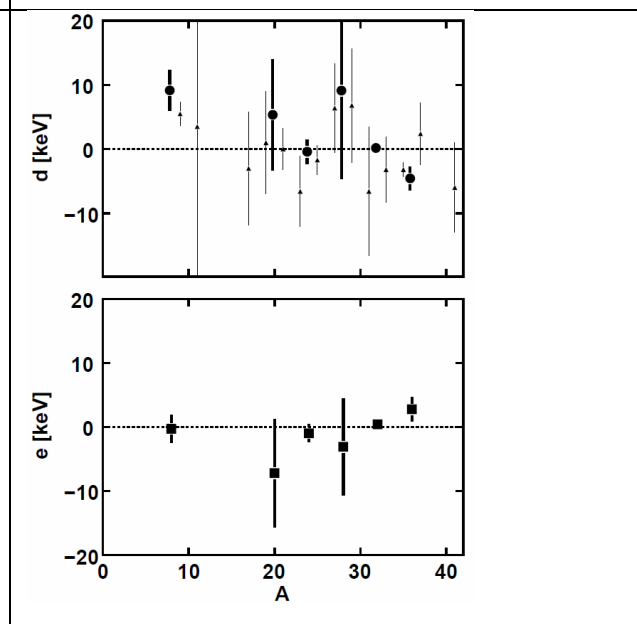


Fig. 2b: The d and e terms of the IMME fit to quintets (circles and squares) and d terms from fits to quartets (small diamonds.) The $A=8$ results include our new mass and width for ${}^8\text{C}_{\text{gs}}$.

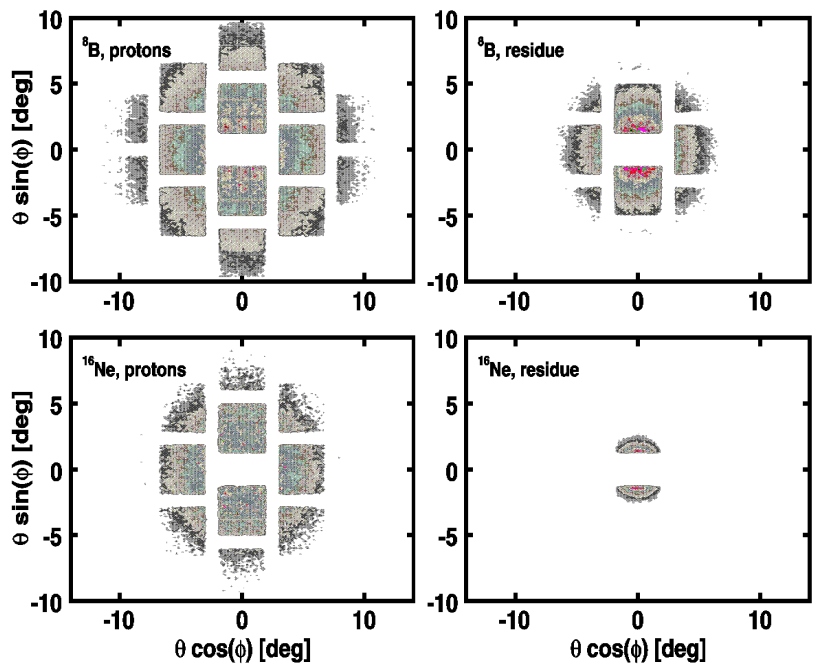
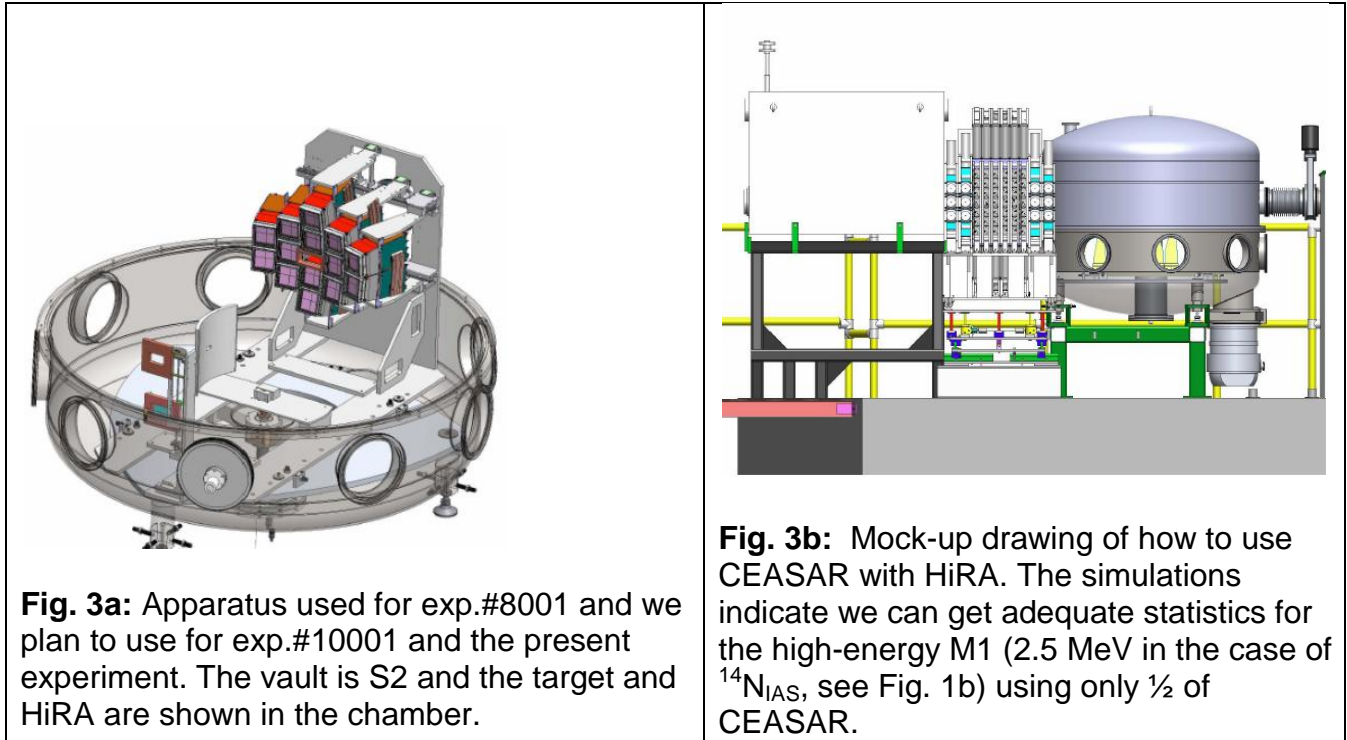


Fig. 4: Simulated hit pattern on the HiRA detectors for protons and the residues in the ^{16}Ne ground state (lower panels) and for comparison $^8\text{B}_{\text{IAS}}$ decays (upper panels). In the case of ^{16}Ne decay, note that only the gains of the two most inner detectors need to have the extended range in order to detect the HI's. (The same is true for the residue of $^{16}\text{F}_{\text{IAS}}$ decay, $^{14}\text{N}_{\text{IAS}}$.)

Status of Previous Experiments

Results from, or status of analysis of, previous experiments at the CCF listed by experiment number. Please indicate publications, invited talks, Ph.D.s awarded, Master's degrees awarded, undergraduate theses completed.

02019

“Particle decay of ^{12}Be excited states,” R. J. Charity, S. Komarov, L. G. Sobotka, J. Clifford, D. Bazin, A. Gade, Jenny. Lee, S. M. Lukyanov, W. G. Lynch, M. Mocko, S. P. Lobastov, A. M. Rogers, A. Sanetullaev, M. B. Tsang, M. S. Wallace, R. G. T. Zegers, S. Hudan, C. Metelko, M. A. Famiano, A. Wuosmaa, M. J. van Goethem, *Phys. Rev. C* **76**, 064313 (2007).

“Investigation of particle-unbound excited states in light nuclei with resonance-decay spectroscopy using a ^{12}Be beam,” R. J. Charity, S. Komarov, L. G. Sobotka, J. Clifford, D. Bazin, A. Gade, Jenny. Lee, S. M. Lukyanov, W. G. Lynch, M. Mocko, S. P. Lobastov, A. M. Rogers, A. Sanetullaev, M. B. Tsang, M. S. Wallace, R. G. T. Zegers, S. Hudan, C. Metelko, M. A. Famiano, A. Wuosmaa, M. J. van Goethem, *Phys. Rev. C* **78**, 054307 (2008).

07009

Neutron and Proton Knockout Cross Sections for ^{36}Ca . *Ph.D. thesis project for Rebecca Shane.* Thesis submitted to and accepted by WU (May 2011), PRC manuscript in preparation.

08001

“ $2p$ - $2p$ decay of ^8C and $2p$ decay of the isobaric analog state in ^8B ,” R.J. Charity, J.M. Elson, J. Manfredi, R. Shane, L.G. Sobotka, Z. Chajecski, D. Coupland, T. Ghosh, H. Iwasaki, M. Kilburn, J. Lee, W.G. Lynch, A. Sanetullaev, M.B. Tsang, J. Winkelbauer, M. Youngs, S. Marley, D.V. Shetty, A.H. Wuosmaa, M. Howard, *Phys. Rev C* **82**, 041304(R) (2010).

“Investigations of three, four, and five-particle exit channels in light nuclei created using a ^9C beam,” R.J. Charity, J.M. Elson, J. Manfredi, R. Shane, L.G. Sobotka, Z. Chajecski, D. Coupland, T. Ghosh, H. Iwasaki, M. Kilburn, J. Lee, W.G. Lynch, A. Sanetullaev, M.B. Tsang, J. Winkelbauer, M. Youngs, S. Marley, D.V. Shetty, A.H. Wuosmaa, M. Howard, *Phys. Rev C* submitted (2011), and available on request.

10001

We requested 247 hrs to study *3pairs of $2p$ decay ($A = 8, 12, \text{ and } 16, \text{ both GS and IAS.}$)* Time was only approved to study the correlations in the $^8\text{B}_{\text{IAS}}$ decay and to do the necessary calibrations. We hope to do this experiment (for $A = 8$) in the fall and couple it with the time requested here to study the $A = 16$ pair. The calibrations needed are common to both, but would have to be repeated if the apparatus was torn down between the runs.

Educational Impact of Proposed Experiment

If the experiment will be part of a thesis project, please include the total number of years the student has been in graduate school, what other experiments the student has participated in at the NSCL and elsewhere (explicitly identify the experiments done as part of thesis work), and what part the proposed measurement plays in the complete thesis project.

This work will be a major part of the thesis work of Tara Mastren (a new graduate student at WU.) Other aspects of the project will serve as the material for the undergraduate “capstone” projects for Juan Manfredi and Marieke Jager. Juan worked on the ${}^8\text{C}/{}^8\text{B}$ data (note his authorship on these works) and he will likely focus on new $A = 8$ data. Marieke and Tara will work on the data collected from the present project - the $A = 16$ $2p$ decays and the IMME results.

Safety Information Worksheet

It is an important goal of the NSCL that users perform their experiments safely, as emphasized in the [Director's Safety Statement](#). Your proposal will be reviewed for safety issues by committees at the NSCL and MSU who will provide reviews to the PAC and to you. If your experiment is approved, a more detailed safety review will be required prior to scheduling and you will need to designate a [Safety Representative](#) for your experiment.

SAFETY CONTACT FOR THIS PROPOSAL: Betty Tsang

HAZARD ASSESSMENTS (CHECK ALL ITEMS THAT MAY APPLY TO YOUR EXPERIMENT):

- Radioactive sources required for checks or calibrations.
- Transport or send radioactive materials to or from the NSCL.
- Transport or send— to or from the NSCL—chemicals or materials that may be considered hazardous or toxic.
- Generate or dispose of chemicals or materials that may be considered hazardous or toxic.
- Mixed Waste (RCRA) will be generated and/or will need disposal.
- Flammable compressed gases needed.
- High-Voltage equipment (Non-standard equipment with > 30 Volts).
- User-supplied pressure or vacuum vessels, gas detectors.
- Non-ionizing radiation sources (microwave, class III or IV lasers, etc.).
- Biohazardous materials.
- Lifting or manipulating heavy equipment (>500 lbs)

PLEASE PROVIDE BRIEF DETAIL ABOUT EACH CHECKED ITEM.

An alpha source is required to calibrate the Si detectors and gamma sources are required to calibrate CEASAR

NSCL PAC 29 Beam Request Worksheet

The S-800 is not used in this experiment

Beam Request Worksheet Instructions

Please use a separate worksheet for each distinct beam-on-target requested for the experiment. Do not forget to include any beams needed for calibration or testing. This form does not apply for experiments based in the A1900. Note the following:

- (a) **Beam Preparation Time** is the time required by the NSCL for beam development and beam delivery. This time is calculated as per item 4. of the Notes for PAC 36 in the Call for Proposals. This time is not part of the time available for performing the experiment.
- (b) **Beam-On-Target Time** is the time that the beam is needed by experimenters for the purpose of performing the experiment, including such activities as experimental device tuning (for both supported and non-supported devices), debugging the experimental setup, calibrations, and test runs.
- (c) The experimental device tuning time (XDT) for a supported device is calculated as per item 5. of the Notes for PAC 36 in the Call for Proposals. For a non-supported device, the contact person for the device can help in making the estimate. In general, XDT is needed only once per experiment but there are exceptions, e.g. a change of optics for the S800 will require a new XDT. When in doubt, please consult the appropriate contact person.
- (d) A **primary beam** can be delivered as an on-target beam for the experiment either at the full beam energy or at a reduced energy by passing it through a degrader of appropriate thickness. The process of reducing the beam energy using a degrader necessarily reduces the quality of the beam. Please use a separate worksheet for each energy request from a single primary beam.
- (e) Report the **Beam-On-Target rate** in units of particles per second per particle-nanoampere (pps/pnA) for secondary beams or in units of particle-nanoampere (pnA) for primary or degraded primary beams.
- (f) More information about **momentum correction** and **timing start signal** rate limits are given in the [A1900 service level description](#).
- (g) For rare-isotope beam experiments, an electronic copy of the LISE++ files used to estimate the rare-isotope beam intensity must be e-mailed to the [A1900 Device Contact](#).

Beam Request Worksheet

Please use a separate sheet for each distinct beam-on-target requested

	Beam Preparation Time	Beam- On- Target Time
Primary Beam (from beam list)		
Isotope	^{20}Ne	
Energy	170	MeV/nucleon
Minimum intensity	75	particle-nanoampere (pnA)

Tuning time (12 hrs; 0 hrs if the beam is already listed in an earlier worksheet): 12 hrs

Beam-On-Target

Isotope	^{17}Ne	
Energy	70	MeV/nucleon
Rate at A1900 focal plane	$5.8 * 10^3$	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	1%	% (e.g. 1%, not $\pm 0.5\%$)
Minimum Acceptable purity	50	% (LISE++ says we should expect 55%).

^{16}F , ^{15}O , ^{14}N all significant contaminates useful for energy calibration. Not ^{14}N is the expect residue in the IAS 2p decay.
Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?

- No
 Yes

What is the desired thickness? 125 μm ; 1000 μm
What is the maximum rate expected for this setting? 10^5 Hz (1 MHz max)

Is event-by-event momentum correction from position measured at the A1900 Image 2 position required?

- No
 Yes

Which detector should be used? Scintillator; PPACs
What is the maximum rate expected for this setting? Hz (1 MHz max)

Delivery time per table (or 0 hrs for primary/degraded primary beam): 2 hrs

Tuning time to vault: 3 hrs

Total beam preparation time for this beam: 5 hrs

Experimental device tuning time [see note (c) above]: 12 hrs

S800 ; SeGA ; Sweeper ; Other

On-target time excluding device tuning: 48 hrs

Total on-target time for this beam: 60 hrs

The expected primary beam energy and intensity were provided by Andreas Stoltz. He bases this on the experience with the primary ^{24}Mg beam at the NSCL. Rate estimates based on the numbers used above and a transmission efficiency of 1/ 3, i.e. 150,000 $^{16}\text{Ne}/\text{s}$ at our secondary target.