National Superconducting Cyclotron Laboratory
Proposal Data Form—PAC 32

TITLE: **Continuum spectroscopy of ^{8}C by alpha+4*p* correlations**

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

SPOKESPERSON: **Lee G. Sobotka**

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BACKUP SPOKESPERSON: **Robert J. Charity**

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OTHER EXPERIMENTERS: (Please spell out first name and indicate Graduate Students (GS), Undergraduate students (UG) and Postdoctoral Associates (PD))

Last name, First name	Organization	Last name, First name	Organization
Shane, Rebecca	WU - GS	Lynch, Bill	MSU
Mueller, Jon	WU - UG	Tsang, Betty	MSU
Wiser, Tim	WU - UG	Henzlova, D.	MSU
		Henzl, V.	MSU
Famiano, Mike	WMU	Rogers, A.	MSU
Wuosmaa, Alan	WMU		

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/nucl.)	Minimum Intensity (particle-nanoampere)	Sum of Beam Preparation Times (Hours)	Sum of Beam-On-Target Times (Hours)
Beam 1	^{16}O	150	100	14+2(6)+4(6)=50	42+48+4(4)=106
Beam 2					
Beam 3					
Beam 4					

ADDITITIONAL 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: | | 156 |

TOTAL TIME REQUEST (HOURS): ___________
(Calculated as per item 4. of the Notes for PAC 32 in the Call for Proposals)

Access to:		SET UP TIME (before start of beam)	TAKE DOWN TIME
	Experimental Vault	__________ days	__________ days
	Electronics Set-up Area	__________ days	__________ days
	Data Acquisition Computer	__________ days	__________ days

NSCL PAC 32 – 3. Proposal Data Form

HOURS APPROVED: ________________ HOURS RESERVED: _____________________

WHEN WILL YOUR EXPERIMENT BE READY TO RUN? ___________ / ________ / _________

DATES EXCLUDED: ____

EXPERIMENTAL LOCATION:

___ Transfer Hall (in the A1900)
___ Transfer Hall (downstream of the A1900)
___ N2 vault (with 92" chamber)
___ N2 vault
___ N2 vault (with Sweeper line)
___ N4 vault (Gas stopping line)
___ S2 vault (Irradiation line)
__X_ S2 vault
_x__ S3 vault (We could run in the s-800 line. This would only make sense, if HiRA was already set-up there.)

EXPERIMENTAL EQUIPMENT:

___ A1900
___ Beta Counting System
___ Beta-NMR Apparatus
___ 92" Chamber
___ Sweeper Magnet
___ Neutron Walls
___ Modular Neutron Array
___ Neutron Emission Ratio Observer
_X_ High Resolution Array
___ Scintillator Array
___ Segmented Ge Array [ ] classic [ ] mini [ ] beta [ ] delta [ ] plunger [ ] barrel [ ] other
___ S800 Spectrograph [ ] with [ ] without scattering chamber
___ Radio Frequency Fragment Separator
__ 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

TARGETS:

_________Be____

LIST ALL RESOURCES THAT YOU REQUEST THE NSCL TO PROVIDE FOR YOUR EXPERIMENT BEYOND THE STANDARD RESOURCES OUTLINED IN ITEM 11. OF THE NOTES FOR PAC 32 IN THE CALL FOR PROPOSALS.

LIST ANY INTERRUPTIONS REQUIRED IN RUNNING 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

OTHER SPECIAL REQUIREMENTS: (Safety related items are listed separately on following pages.)

SUMMARY (no more than 200 words):

A 5-particle correlation experiment is being proposed to study the decay of ^{8}C created via neutron knockout from ^{9}C. The role of high-order phase space will be determined from the strength of the $^{6}Be_{gs}$ correlation. We also propose to set-up and debug the apparatus using ^{6}Be decay (created with neutron knockout from ^{7}Be). This would also create a kinematically complete data set of this 2*p* correlation.

Description of Experiment

(no more than 4 pages of text for items 1through 3 - 1 1/2 spaced, 12pt; no limit on figures or tables)

Please organize material under the following headings or their equivalent:

1. Physics justification, including background and references.
2. Goals of proposed experiment
3. Experimental details—apparatus (enclose sketch); what is to be measured; feasibility of measurement; count rate estimate (including assumptions); basis of time request (include time for calibration beams, test runs, and beam particle or energy changes); technical assistance or apparatus construction requested from the NSCL.

Note: Graphics should be such that black-and-white copies will convey the intended information correctly; references to color should be avoided.

i. Physics Justification

Figure 1 shows that ^{8}C is bound with respect to ^{7}B+*p* decay by a small fraction of the relevant widths (either $^{8}C_{gs}$ or $^{7}B_{gs}$), and unbound wrt ^{6}Be+2*p* decay (by 2.14 MeV), ^{5}Li+3*p* (1.55 MeV), and ^{4}He+4*p* (3.51 MeV).

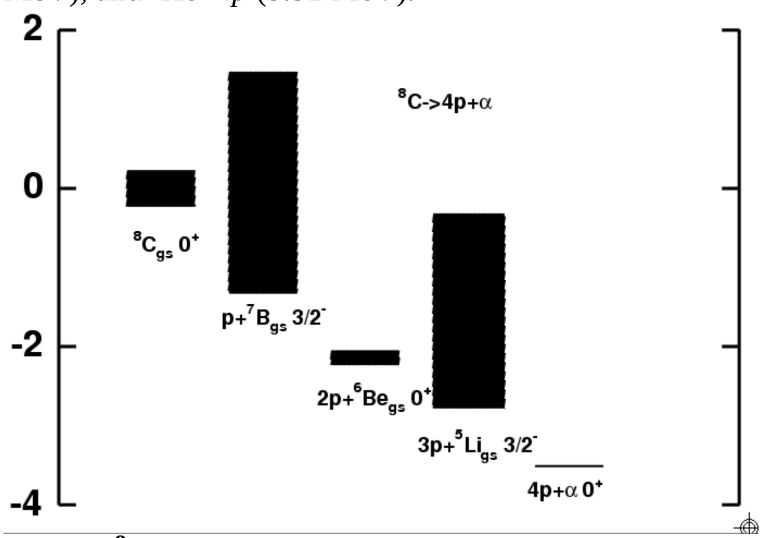

Fig. 1: ^{8}C and its decomposition products.

One cannot consider sequential decays to ^{7}B and ^{5}Li ground states as their widths are so wide that they will themselves decay while the other decay products are still in the vicinity and therefore, at a minimum, one must consider final-state interactions between the initial and final fragments. ^{8}C will ultimately decay to ^{4}He+4*p*, with the only possible narrow intermediate being ^{6}Be with a width 93 keV. If the decay does not pass through this intermediate, then the decay must be considered 5-body in nature. This experiment will answer the question: Does the ground state of ^{8}C decay through the ground state of $^{6}Be_{gs}$? That is - does the decay proceed through ^{8}C ➔ $^{6}Be_{gs}$ +2*p* ➔ α+4*p*? (two sequential 3-body decays). The presence of $^{6}Be_{gs}$ is determined by a 92 keV wide reconstructed E* correlation between the α and 2 p's. As there are 3! ways to construct the α+2*p* correlation from the α+4*p* events, the experimental correlation signal is admixed with the 5 improper ways of constructing the α+2*p* correlation.

The stronger the $^6Be_{gs}$ correlation, the less important the 4 and 5-particle phase phases are to the decay. If the decay does proceed through $^6Be_{gs}$**,** the correlation of the first two protons will be measured, analyzed to extract both the relative energy and angle of the (first) two protons and compared to Fadeev calculations [1] and presented using the Jacobi "T" and "Y" coordinates[2]. This analysis is complicated by the dilution of 1:5, with the improperly constructed correlations. Note as the ^{6}Be intermediate is J=0, there are no correlations between the protons emitted in the different steps. Only within a step can there be correlations and those from the decay of ^{6}Be will be measured separately (see later). As shown in the simulations presented below, the dilution will create a background in the region of the resonance about equal to the ^{6}Be resonance yield (if 100% of the time there is a $^6Be_{gs}$ intermediate.)

Of course, we will also look for excited states of ^{8}C by the presence of additional peaks in the reconstructed E*(^{8}C=α+4*p*) and infer their decay paths too. Presently the only the ground-state energy and width (Δ = 35.094, Γ = 230 keV) are known for ^{8}C.

We also propose to collect direct ^{6}Be data with a secondary ^{7}Be beam. Neutron knockout from this secondary beam will provide a nice calibration of the correlation that we need to gate on in the α+4*p*, ^{9}C data (free of the background of wrongly correlated particle combinations). Equally important it will provide the kinematically complete data needed for a Jacobi analysis of ^{6}Be[2]. In a three-body decay the correlations between all of the three fragments can be described by two dimensional distributions. One can choose either the Jacobi "T" or "Y" representation. Although there are a number of 2*p* and 2*n* decays observed from ground and excited states of other nuclei, ^{6}Be represents one of the few cases where the production rate is substantial and the particle detection is straightforward which allows for full and accurate 2-dim Jacobi distributions to be measured with adequate statistics. A measurement these distributions for ^{6}Be would therefore provide a bench mark for theoretical calculations of 3-body decay. Grigorenko has provided predictions of this correlation which we plan to compare to experimental data, see **Fig. 2**. Past studies of ^{6}Be breakup are not kinematically complete or have insufficient statistics for a Jacobi analysis[3].

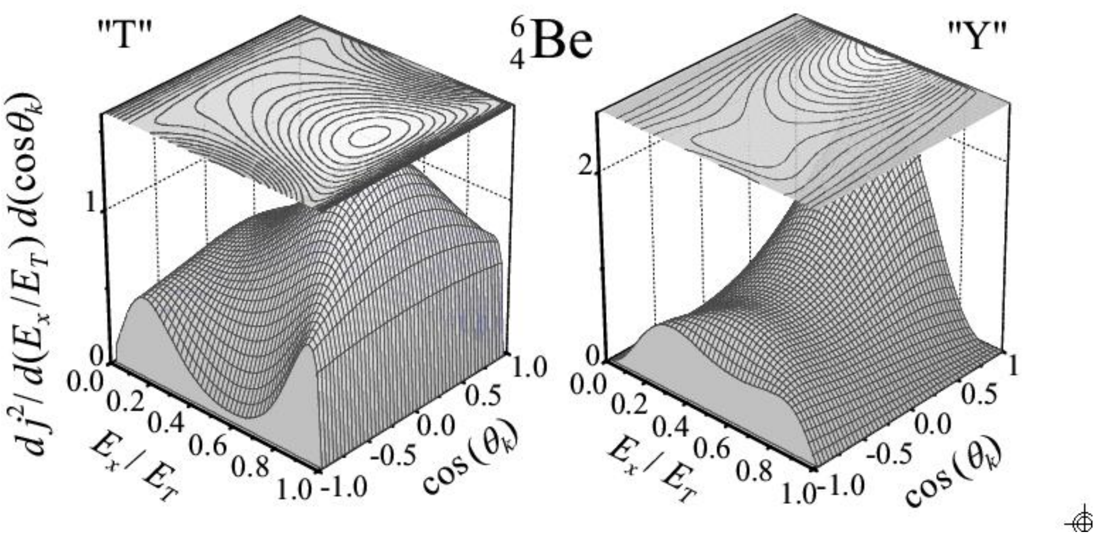

Fig. 2:

Some relevant History

Over 10 years ago we worked with Mike Thoennessen to study the 2*p* decay of ^{12}O [4]. That work used the WU MINI-WALL. Recently we have used far superior technology (HiRA) to study the continuum structure of ^{10}C [5]. The proposed experiment can be viewed as filling in the data on the continuum structure and multi – p decay between these cases and ^{6}Be, the first identified 2p emitter [3]. Our proposed experiment is also designed to get kinematically complete (direct) data on ^{6}Be decay.

No evidence was found for correlated 2p emission in ^{12}O [4]. Our recent work [5] on ^{10}C was more interesting and more involved. Here we detected the 2α+2p decay channel for excited ^{10}C states. We were able to determine the decay paths of the known levels in ^{10}C, one of which exhibits a correlated 2p emission to the ^{8}Be ground state, i.e. not sequential or 3-body phase-space (**Fig. 3**). We also found a previously unknown state and determined how it decays (**Fig. 4**). Thus we have demonstrated that we can detect and measure 4-particle correlations with adequate sensitivity and reconstruct the decay mechanisms. In the present proposal, we wish to extend this to 5-particle correlations.

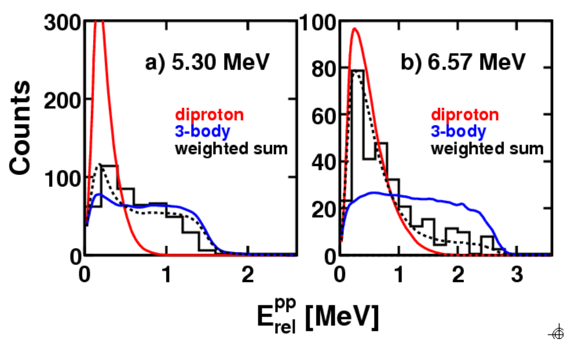

Fig. 3: 2p relative energy from a) the 5.3 MeV and 6.6 MeV states in ^{10}C. The lower of these excited states is consistent with 3-body phase-space decay while the latter requires a correlation which is well described by R-matrix or Faddeev calculations[4].

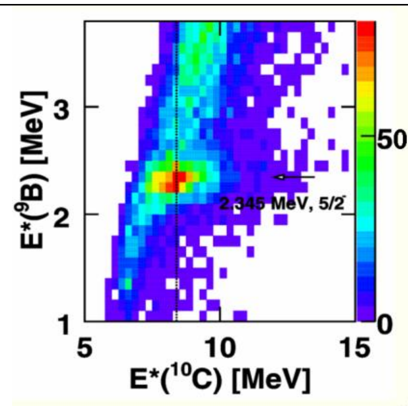

Fig. 4: Newly discovered state in ^{10}C (at 8.6 MeV) which decays through the 2.35 MeV state in ^{9}B.

Goals of the proposed experiment

Our goals are simply: to a) determine how the ground state of ^{8}C decays, b) search for excited states in ^{8}C, and c) collect kinematically complete data on ^{6}Be decay.

ii. Experimental Details

This experiment will make use of HiRA in the geometry indicated in **Fig. 5** in S2, in the new chamber, or in S3, in the S800 chamber. (The location should be chosen by consideration of facility convenience and be mated with other runs where HiRa is assembled.) In either location/chamber, the target would have to be moved to an upstream location, so that the target to HiRA distance is about 1 m.

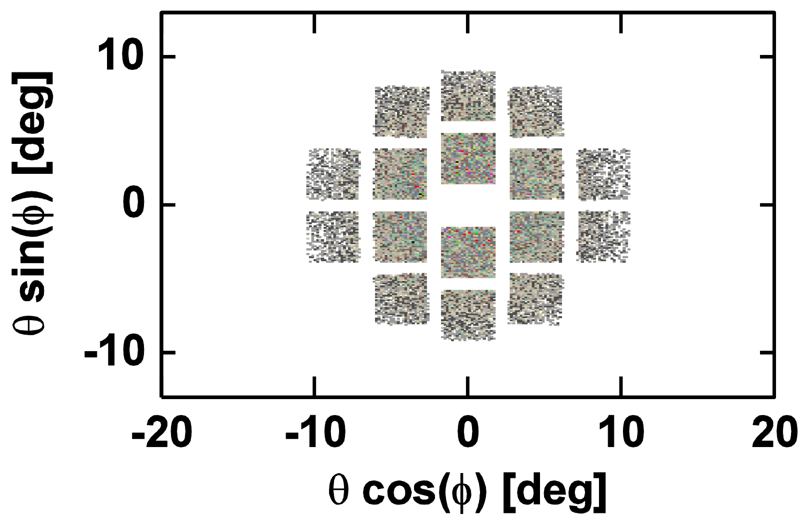

Fig. 5: This geometry has 16 HiRA detectors (in 5 towers) at just over 1 m from the target. The telescope arrangement has a central one removed for the beam. The simulated efficiency is approximately 2.8 % for α+4*p* events. (See included table for simulation parameters.)

Simulations were preformed with several geometries and we have settled on one (indicated in

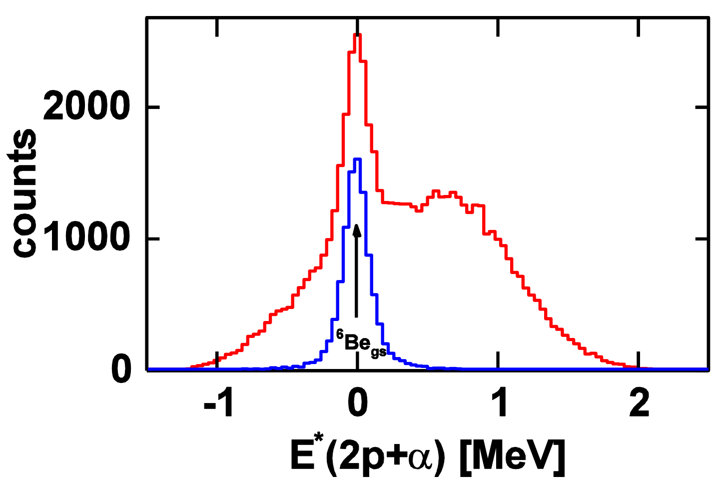

Fig. 6: α+2*p* correlation from (50,000 total) α+4*p* events. (See discussion of the efficiency in the text.) The assumed CsI(Tl) resolution is 2.0 % (FWHM), a value consistent with the value found in recent HiRA experiments. The effects of: the experimental angular resolution, energy loss, and small angle scattering of the particles in the target, are all included.

The red curve in Fig. 6 shows the reconstructed α+2*p* correlation (3! per event) when ^{8}C decays 100% through ^{6}Be. The correct correlation for ^{6}Be (known to the simulation) is shown in blue. The width of this peak, including the experimental resolution, is simulated to be 190 keV, however the data from the ^{7}Be beam will allow us to determine this experimentally. The ^{6}Be correlation would clearly be seen (over the wrongly correlated background) if the decay were to proceed this way. If the yield in the ^{6}Be peak is smaller, a branching ratio for this decay will be extracted. For these simulations, we used the resolutions determined from previous HiRA experiments. (The CsI(Tl) resolution is the primary issue here.) As will be discussed below, the efficiency of the apparatus to this 5-particle correlation experiment depends crucially on the assumed transverse momentum distribution.

Time estimates

The *p* knock-out from ^{9}C proceeds with a measured cross section of 54 mb[6]. The *n* knockout from ^{24}Si has a measured cross section of 10 mb [7]. The first is the removal of a weakly bound particle (but from the nucleus of interest) while the later is the removal of a very strongly bound particle (as in our case), but from a different nucleus. The trend with separation energy has been studied by knockout reactions at NSCL [8] and through our Dispersive Optical Model (DOM) analysis of elastic scattering [9]. Considering these systematics we used a value of 10 mb for the neutron knockout from ^{9}C. (This would correspond to a very small spectroscopic reduction factor of ~ 0.2, a conservative value.)

The efficiency of HiRA to the 5 particle events is very sensitive to the transverse momentum distribution. This was estimated with the MOMDIS code [10]. Using the MOMDIS distribution, the efficiency is less than 1% if HiRA were run at its standard distance ~ 50 cm (with the central detector missing for the beam to go though). The efficiency can be increased to ~ 2.8 % if we move the target up stream and ran HiRA at ~ 100 cm. This can be done either in the new S2 chamber (with the upstream target position) or in the S-800 chamber.

Input numbers for rate estimate and simulations

Quantity	**value**	**source**
σ_{-n}	10mb	[6,7]
eff	0.028	simulations
^{9}C	10^{5}/s	LISE (1.3 x 10^{3} [^{9}C/pna(^{16}O)] x 125 pna)
Target (^{9}Be)	100 mg/cm^{2}	
$P_{transverse}$	260 MeV/c FWHM	[10] code MOMDIS

With these values we expect 0.16 events/s. Dead-time may slightly lower this number (we will have to trigger on high multiplicity from the CsI(Tl) HiRA detectors) but nevertheless, using the MOMDIS transverse-momentum distribution we will collect ~ 14,000 events/day. (The simulations in Fig. 6 have 50,000 events.) Thus two days of good data will be sufficient. (Allowing less time would not be prudent considering the strong sensitivity to $P_{transverse}$ and the time invested by the facility and us.)

As the LISE simulations indicate essential pure beams (for both ^{7}Be and ^{9}C), and the reconstructed E* does not depend on tracking, we do not intend to track. (Tracking with such intense secondary beams is not possible anyways.) We will measure the TOF from the end of the A1900 to HiRA. However, as we do not need this event by event, we can extract the scintillator after confirming the secondary beam quality. (We would leave it in, if the scintillator lifetime, at the delivered rate, is commensurate with the duration of the experiment.)

In addition, time is requested for a direct ^{7}Be beam. We plan to not only debug HiRA with this beam but also do the very useful "sub-set" experiment of knocking-out a n and detecting the α + 2*p* decay channel of ^{6}Be. This will provide a nice calibration of the correlation that we need to gate on in the ^{8}C experiment (free of the wrongly correlated particle combinations.) Equally important it will provide the kinematically complete data needed for the Jacobi analysis.

In addition to the beam time to collect these two data sets, time is also requested to deliver two energies of both alpha and protons for calibration. This time could be reduced (but not eliminated), if this experiment is dove-tailed to another HiRA experiment in the same location.

Other considerations
We would hope to use an existing HiRA mount. However WU can fabricate a mount, designed at the NSCL, if necessary.

References
1. C. Fu, et al., PRC 76, 021603 (2007), and primate communication with A.M. Mukhamedzhanov.
2. L.V. Grigorenko et al., PRL **85**, 22 (2000), PRC **68**, 054005 (2003) and private communication.
3. D.F. Geesaman, et al., PRC 15, 1835 (1977) and
O.V. Bochkarev et al., Sov. J. Nucl. Phys. **44**, 955 (1992)
4. R.A. Kryger, et al. PRL **74**, 860 (1995).
5. R.J. Charity, et al., PRC **75**, 051304 (2008) and K. Mercurio et al., manuscript in preparation.
6. J. Enders et al., PRC **67**, 06431 (2003).
7. A. Gade, et al., PRC manuscript (2008).
8. A. Gade, et al., PRL, **93**, 042501 (2004).
9. R.J. Charity, et al,. PRL **97**, 162503 (2006) and PRC **76**, 044314 (2008).
10. C. Bertulani and A. Gade, CPC 17, 372 (2006), CODE MOMDIS. (The potential was adjusted to reproduce the *n* separation energy.)

Status of Previous Experiments

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

01002 – Nuclear structure viewed through a a wide angle lens (Sobotka)
This experiment did not work. However a successful experiment at ANL, addressing the related physics, was the basis for a thesis and a long PRC paper. PRC 75, 064611 (2007).

02019 – Resonance spectroscopy of ^{12}Be (Charity). One paper is in print [PRC 76, 064313 (2007)] concerning ^{12}Be and another paper is on the resonance structure of other nuclei populated in this experiment is nearing completion.

07009 - Neutron and Proton Knockout Cross Sections for ^{36}Ca (Charity) will be done this summer.

Two other related (resonance spectroscopy) experiments should be mentioned in the context of this proposal. Two experiments on ^{10}C were done at TAMU. One, done in the summer of 2006, lead to a rapid communication [PRC 75, 051304 (2007)]. The second, done in the summer of 2007, has been completely analyzed and will be submitted soon. These experiments are mentioned here and in the proposal text, to illustrate that the "machinery" to analyze these resonance spectroscopy experiments exists and has been extensively exercised.

Educational Impact of Proposed Experiment

If the experiment will be part of a thesis project, please include how many years the student has been in 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 whether the proposed measurement will complete the thesis work.

This experiment will not be part of the PhD thesis. It will be used for an undergraduate thesis (for Tim Wiser.) Please keep in mind that all the hardware and software for this project have been used in several previous decay spectroscopy experiments by the WU group.

Safety Information

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 review will be required prior to scheduling and you will need to designate a Safety Representative for your experiment.

SAFETY CONTACT FOR THIS PROPOSAL:
____

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

____**X**___ 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.

PLEASE PROVIDE BRIEF DETAIL ABOUT EACH CHECKED ITEM.

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 32 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 32 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.

NSCL PAC 29 Beam Request Worksheet

Primary beam dev, system debug down, and alpha-2p correlation – 14 +30 = 44 hours

			Beam Preparation Time	Beam-On-Target Time
Primary Beam (from beam list)				
Isotope	**^{16}O**			
Energy	**150**	MeV/nucleon		
Minimum intensity	**100**	particle-nanoampere		
Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet):			14 hrs	
Beam-On-Target				
Isotope	**^{7}Be**			
Energy	**70**	MeV/nucleon		
Rate at A1900 focal plane	**10^5**	pps/pnA (secondary beam) or pnA (primary beam)		
Total A1900 momentum acceptance	**1**	% (e.g. 1%, not ±0.5%)		
Minimum Acceptable purity	**95**	%		
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator		
	[ ]	Timing start signal from A1900 extended focal plane		
Delivery time per table (or 0 hrs for primary/degraded primary beam):			2 hrs	
Tuning time to vault:			4 hrs	
Total beam preparation time for this beam:			**6 hrs**	
Experimental device tuning time [see note (c) above]: S800 [ ] SeGA [ ] Sweeper [ ] Other [X] HiRA				18 hrs
On-target time excluding device tuning:				24 hrs
Total on-target time for this beam:				**42 hrs**

Beam Request Worksheet

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

Primary Data on 9C – 30 hours

			Beam Preparation Time	Beam-On-Target Time
Primary Beam (from beam list)				
Isotope	**^{16}O**			
Energy	**150**	MeV/nucleon		
Minimum intensity	**100**	particle-nanoampere		
Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet):			hrs	
Beam-On-Target				
Isotope	**^{9}C**			
Energy	**70**	MeV/nucleon		
Rate at A1900 focal plane	**10^5**	pps/pnA (secondary beam) or pnA (primary beam)		
Total A1900 momentum acceptance	**1**	% (e.g. 1%, not ±0.5%)		
Minimum Acceptable purity	**95**	%		
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator		
	[ ]	Timing start signal from A1900 extended focal plane		
Delivery time per table (or 0 hrs for primary/degraded primary beam):			2 hrs	
Tuning time to vault:			4 hrs	
Total beam preparation time for this beam:			**6 hrs**	
Experimental device tuning time [see note (c) above]: S800 [ ] SeGA [ ] Sweeper [ ] Other [X] HiRA				0 hrs
On-target time excluding device tuning:				48 hrs
Total on-target time for this beam:				**48 hrs**

Beam Request Worksheet

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

Alpha Calibration – 1 : 10 hrs

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope: ^{16}O
Energy: **150** MeV/nucleon
Minimum intensity: **100** particle-nanoampere

Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet): [ ] hrs

Beam-On-Target

Isotope: 4He
Energy: **60** MeV/nucleon
Rate at A1900 focal plane: **10^3** pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance: **1** % (e.g. 1%, not ±0.5%)
Minimum Acceptable purity: **95** %
Additional requirements: [ ] Event-by-event momentum correction from position in A1900 Image 2 measured with
[ ] PPAC
[ ] Scintillator
[ ] Timing start signal from A1900 extended focal plane

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

Tuning time to vault: **4** hrs

Total beam preparation time for this beam: 6 hrs

Experimental device tuning time [see note (c) above]: **0** hrs
S800 [ ] SeGA [ ] Sweeper [ ] Other [**X**] HiRA
On-target time excluding device tuning: **4** hrs

Total on-target time for this beam: 4 hrs

Beam Request Worksheet

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

Alpha Calibration – 2 : 10 hrs

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	^{16}**O**	
Energy	**150**	MeV/nucleon
Minimum intensity	**100**	particle-nanoampere

Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet): [ ] hrs

Beam-On-Target

Isotope	4He	
Energy	**80**	MeV/nucleon
Rate at A1900 focal plane	**10^3**	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	**1**	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity	**95**	%
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator
	[ ]	Timing start signal from A1900 extended focal plane

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

Tuning time to vault: **4** hrs

Total beam preparation time for this beam: 6 hrs

Experimental device tuning time [see note (c) above]: **0** hrs
S800 [ ] SeGA [ ] Sweeper [ ] Other [X] HiRA
On-target time excluding device tuning: **4** hrs

Total on-target time for this beam: 4 hrs

Beam Request Worksheet

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

p Calibration – 1 : 10 hrs

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	**^{16}O**	
Energy	**150**	MeV/nucleon
Minimum intensity	**100**	particle-nanoampere

Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet): [ ] hrs

Beam-On-Target

Isotope	p	
Energy	**60**	MeV/nucleon
Rate at A1900 focal plane	**10^3**	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	**1**	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity	**90**	%
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator
	[ ]	Timing start signal from A1900 extended focal plane

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

Tuning time to vault: **4** hrs

Total beam preparation time for this beam: 6 hrs

Experimental device tuning time [see note (c) above]: **0** hrs

S800 [ ] SeGA [ ] Sweeper [ ] Other [**X**] HiRA

On-target time excluding device tuning: **4** hrs

Total on-target time for this beam: 4 hrs

Beam Request Worksheet

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

p Calibration – 2 : 10 hrs

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	**^{16}O**	
Energy	**150**	MeV/nucleon
Minimum intensity	**100**	particle-nanoampere

Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet): [   ] hrs

Beam-On-Target

Isotope	p	
Energy	**80**	MeV/nucleon
Rate at A1900 focal plane	**10^3**	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	**1**	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity	**90**	%
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator
	[ ]	Timing start signal from A1900 extended focal plane

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

Tuning time to vault: **4** hrs

Total beam preparation time for this beam: **6** **hrs**

Experimental device tuning time [see note (c) above]: **0** hrs

S800 [ ]   SeGA [ ]   Sweeper [   ]   Other [X] HiRA

On-target time excluding device tuning: **4** hrs

Total on-target time for this beam: **4** **hrs**