National Superconducting Cyclotron Laboratory
Proposal Form - PAC 37

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

TITLE: Neutron Knockout in Neutron-Rich Ca Isotopes

SPOKESPERSON: Heather Crawford
ADDRESS: Lawrence Berkeley National Laboratory , 1 Cyclotron Road, MS88R0192 , Berkeley, CA 94703
PHONE: 510-486-5702
FAX: 510-486-7983
EMAIL: hlcrawford@lbl.gov
ORGANIZATION: Lawrence Berkeley National Laboratory
POSITION: PD

BACKUP SPOKESPERSON: Augusto O. Macchiavelli
ADDRESS: Lawrence Berkeley National Laboratory , 1 Cyclotron Road, MS88R0192 , Berkeley, CA 94703
PHONE: 510-486-4428
FAX: 510-486-7983
EMAIL: AOMacchiavelli@lbl.gov
ORGANIZATION: Lawrence Berkeley National Laboratory
POSITION: SR

Other Experimeters:

Name	**Organization**	**Position**
Roderick Clark	LBNL	SR
Paul Fallon	LBNL	SR
I-Yang Lee	LBNL	SR
Mario Cromaz	LBNL	SR
Chris Campbell	LBNL	PD
Alexandra Gade	NSCL	SR
Dirk Weisshaar	NSCL	SR
Robert Janssens	ANL	SR
Mike Carpenter	ANL	SR
Shaofei Zhu	ANL	SR
Torben Lauritsen	ANL	SR
Reiner Krucken	TRIUMF	SR
Jens Dilling	TRIUMF/UBC	SR
Aaron Gallant	TRIUMF/UBC	GS
Achim Schwenk	TU-Darmstadt	SR
Javier Menendez	TU-Darmstadt	PD
Jason Holt	ORNL/UT	SR
Ragnar Stroberg	NSCL	GS
Vincent Bader	NSCL	GS
Kathrin Wimmer	NSCL	PD
Francesco Recchia	NSCL	PD
Travis Baugher	NSCL	GS

Request for primary beam sequence including tuning, test runs, and in-beam calibrations:

	Isotope	**Energy**	**Minimum Intensity**
Beam 1	82Se	140 MeV/Nucleon	35 pnA

Sum of Beam Preparation Times	39 hours
Sum of Beam-On-Target Times	142 hours
Additional CCF Use Time	hours
Total Time	181 hours

EXPERIMENTAL LOCATION: S3 Vault
EXPERIMENTAL EQUIPMENT: A1900
GRETINA
S800 spectrograph without scattering chamber

	Setup Time (Days)	Take Down Time (Days)
Access to Experimental Vault:	2	2
Access to Electronic Setup:	2	2
Access to Data Acquisition Computer:	2	2

Date when experiment will be ready to run: 2012-07-01
Dates excluded:

Detail any modifications needed to the standard configuration of the device used:
Requirements that are outside the current NSCL operating envelope:
Reaction targets at the experimental station:
List any breaks required in the schedule of your experiment:
Non-standard resources:
Other special requirements:

SUMMARY:

We propose to study the neutron-knockout along the Ca isotopic chain, in order to measure the neutron spectroscopic factors in ^{47,48,49}Ca. Recent calculations by Holt *et al.*, have suggested that the inclusion of 3N forces to describe the structure of neutron-rich Ca isotopes provides an improvement to the predicted properties, such as the magicity of ^{48}Ca, and the binding energies. These calculations also suggest that in ^{50}Ca, there should be a reduction of the $f_{7/2}$ neutron occupancy, resulting from a narrowing of the N=28 gap in ^{50}Ca. We will investigate this prediction by measuring the spectroscopic factors directly, for the ^{50}Ca ? ^{49}Ca knockout, and comparing to theoretical expectations. We will also measure knockout from ^{48}Ca, as a calibration case, as ^{48}Ca is a good doubly-magic nucleus and the spectroscopic factors are known, and from ^{49}Ca, to compare the g.s. to g.s. knockout spectroscopic factors with those obtainted in ^{48}Ca(d,p)^{49}Ca reactions.

NSCL PAC 37 – 1. Description of Experiment

I. Physics Justification

A central theme in nuclear structure physics is the evolution of shell structure with isospin, and the changes in nucleon single-particle energies as one moves away from stability towards the driplines. The shell model is robust near stability, but has been shown to be modified in nuclei away from the valley of beta stability. Significant effort has been directed, both experimentally and theoretically to understanding the changes in shell structure as a function of neutron excess (see e.g. [So08] and references therein), and a comprehensive picture is developing in many regions of the nuclear chart. However, open questions remain, both specific to the evolution of important nucleon single-particle orbitals, and more generally to the current understanding of the forces required to describe the structure of nuclei.

Of particular interest is the structure of neutron-rich Ca isotopes around N=32, 34. Recent state of the art calculations using the phenomenological interactions GXPF1 and KB3G reproduce well the known level structure up to A=52, but predict different behaviors for ^{54}Ca. Interestingly, recent theoretical work by Holt *et al*. [Ho11] has suggested that the Ca isotopes may be in a region of the nuclear chart where 3-body (3N) forces result in important modifications of nuclear structure. NN-only calculations don't reproduce the shell closure at N=28 in the Ca isotopes, and it has been suggested that the modifications required in phenomenological models to reproduce the doubly-magic character of ^{48}Ca are largely due to neglected 3N forces. These new calculations no longer support a N=34 shell-closure as is predicted by the GXPF1A phenomenological model, and provide considerable improvements to the theoretical ground state energies of Ca isotopes in the region. It seems natural that mass measurements of these exotic Ca isotopes will provide important information for the theoretical models, an experimental avenue being explored at TRIUMF by Gallant *et al* [Ga12].

While level structures of ^{49}Ca-^{52}Ca are available from deep-inelastic studies [e.g. Br01, Br05, Fo08, Mo11] and knockout reactions [Ga06], we can gain more insight by looking into the single-particle components of the ground and excited-state wavefunctions by direct single neutron knockout reactions. While some data exist for knockout in the Ca isotopes near ^{49}Ca in a conference proceeding [Kr08], the picture remains incomplete. Beam intensities are not yet sufficient to directly probe beyond N=32 in the Ca isotopes, but knockout reactions are possible in the lighter isotopes as experimental rates are higher, so that one can reach as far as knockout from ^{50}Ca$_{30}$.

In Fig. 1, we reproduce the calculated ESPE of Holt *et al*. [Ho11]. An inspection of these calculated levels indicates that the computed single-particle energy-level spacings are quite sensitive to the inclusion of 3N forces in this theoretical framework. As seen in Fig. 1(c), the $2p_{3/2}$ and $1f_{7/2}$ neutron orbitals are nearly degenerate at N=30 when the NN+3N forces are included, while the phenomenological models exhibit a significant gap. In the case that these two neutron orbitals become degenerate and the N=28 gap is quenched in ^{50}Ca, one would expect mixing between them, and the spectroscopic factors for neutron knockout would be sensitive to the degree of mixing. In other words, with the realistic NN and 3N forces included, while ^{48}Ca is doubly-magic, the N=28 gap is quenched already at ^{50}Ca, and the $1f_{7/2}$ neutron orbital may not be full. (Properly speaking, the erosion of the N=28 gap in the ESPEs seems to be mainly the effect of the realistic NN forces, rather than that of the 3N component.) In this case, the $f_{7/2}$ sum rule would be depleted, which will be evident in the spectroscopic factors for knockout into the state. This qualitative explanation is borne out by the actual calculated spectroscopic factors [Sc12] provided in Fig. 2 for the knockout of $^{50}Ca_{gs}$ to ^{49}Ca. Note the large difference expected between the GXPF1 and the realistic force with 3N components. This quenching of the $f_{7/2}$ sum rule may possibly be one of the clearest indications for the role of 3N forces in the Ca isotopes. The results discussed above also show that the $g_{9/2}$ and $f_{5/2}$ levels are very close in energy in ^{50}Ca. The recent experiment at Legnaro [Mo11] established a $9/2^+$ state at ~4 MeV that has been interpreted as resulting from a coupling of the 3^- phonon in ^{48}Ca with an unpaired $p_{3/2}$ neutron, where the 3^- excitation in ^{48}Ca is explained as arising from a $s_{1/2}$ or $d_{3/2}$ proton being promoted across the N=20 gap into the $1f_{7/2}$ level. If this is the case, this state should not be populated in the neutron knockout measurement. If however, population of the 4.0 MeV state in ^{49}Ca is observed, this would provide first evidence for contributions of the $\nu 1g_{9/2}$ orbital.

II. Goals of the proposed experiment

The goals of the proposed experiment are to measure the low-energy states in the neutron rich ^{47,48,49}Ca isotopes following neutron knockout, and determine spectroscopic factors for the populated excited states and ground states. This new spectroscopic data will provide unique data to confront the new calculations, describing the $_{20}$Ca isotopes using realistic NN + 3N forces. It may also identification of possible contributions from the $1g_{9/2}$ neutron orbital which is expected to drop in energy.

NSCL PAC 37 – 2. Status of Previous Experiments

III. Experimental Details

We are proposing to use one-neutron knockout reactions ^{9}Be(^{A}Ca, $^{A-1}$Ca+γ)X, for A=48, 49 and 50 and in-beam γ-ray spectroscopy using GRETINA to study the excited states in ^{47,48,49}Ca. We plan to detect the reaction residues in the focal plane of the S800, operated in focus mode, as has been done in the past for these types of reactions. The proposed measurement will involve 3 separate setting of the A1900, centered on ^{48,49,50}Ca, where the primary contaminants in each case will be the V isotope four mass units above the Ca isotope of interest.

Secondary Beam Production and Rates

The secondary beams of ^{48,49,50}Ca will be produced by projectile fragmentation of a 140 MeV/nucleon ^{82}Se primary beam in a 525 mg/cm^2 Be target placed at the object position of the A1900 fragment separator. The desired fragments will be separated from other reaction products using a 500 mg/cm^2 Al wedge at the intermediate dispersive image of the A1900. Simulations using the program LISE++, version 9.3 [Ta04, Ba02], give the production rates for ^{48,49,50}Ca as shown in Table 1, using a 1% momentum acceptance of the A1900. The minimum primary beam current expected for 140 MeV/nucleon ^{82}Se is 35 pnA, giving a lower limit for the production rate of the most exotic nucleus, ^{50}Ca, at the A1900 focal plane of ~2460/s. However, based on previous NSCL experiments using a ^{76}Ge primary beam in this section of the nuclear chart (NSCL Experiment 05101), LISE++ estimates for yields of rare isotopes were shown to be overestimated in the region by, on average, a factor of 5. Conservatively assuming that the overestimation in rare-isotope yields is similar for the ^{82}Se primary beam, the rate of ^{50}Ca expected at the A1900 focal plane is 492/s. The rates for the two secondary beams are given in Table 1, taking into account 50% transmission from the A1900 focal plane to the S3 vault. Identification of the cocktail beams impinging on the S800 target position will be achieved using the difference in time-of-flight between the A1900 extended focal plane and the S800 object scintillators. This method has been used successfully in previous S800 knockout experiments.

Experiment Set-Up

This measurement will use the combination of GRETINA and the S800 spectrograph for coincident particle-γ spectroscopy. The seven GRETINA modules will be used at forward angles, with four detectors in the first ring at $\theta = 58°$, and the other three in a close configuration in the second ring at $\theta = 90°$. The high resolution of GRETINA as compared to CAESAR will allow us to resolve closely-spaced gamma-ray transitions near 4 MeV, while the efficiency gain as compared to SeGA makes the measurement feasible within a reasonable length of beam time. At the target position of GRETINA, a 400 mg/cm^2 ^{9}Be target will induce neutron-knockout reactions. Reaction residues will be detected and identified in the S800 focal plane detectors, with additional information coming from beam-line timing detectors. Reconstruction of flight trajectories through the S800 and momentum distributions will be achieved using positions and angles in the focal plane as measured using the position-sensitive CRDC detectors, and inverse maps for the spectrograph.

Reaction Rates and Beam Time Request

We propose to first measure the neutron knockout for ^{48}Ca to ^{47}Ca. ^{48}Ca is a good doubly-magic nucleus, and knockout into ^{47}Ca will thus serve as an excellent calibration measurement, as the states in ^{47}Ca are also well known, as are the spectroscopic factors. With the high rate of ^{48}Ca, only 4 hours of beam on target time is requested for this calibration measurement. We will then measure the knockout for ^{49}Ca to ^{48}Ca -- the ^{48}Ca(d,p)^{49}Ca reaction [Uo94] has been studied in detail, and we will be able to confirm the results of that work by studying the complementary knockout. Our results for the g.s. to g.s. spectroscopic factors should be consistent with those extracted in the (d,p) measurement. With a secondary beam rate of 1100 pps at the S800 target position, we request 24 hours to perform a detailed measurement of the ^{49}Ca → ^{48}Ca knockout. For the target case of ^{50}Ca → ^{49}Ca, to make a detailed momentum distribution measurement and extract spectroscopic factors for a given state, we require 1000 particle-gamma coincidence events. Assuming a nominal 10 mb single-particle cross-section, estimates for the expected gamma-ray rates are presented in Table 2 for the knockout of ^{50}Ca to ^{49}Ca. We request 100 hours of beam time to study this knockout reaction. With this beam time, we will be able to make a high-statistics measurement for the 3.36 MeV state, which will give us information regarding the occupancy of the $1f_{7/2}$ orbital, which is expected to be reduced if 3N forces close the N=28 gap as predicted. In addition, we expect to obtain a few hundred counts in the 3.99 MeV distribution, sufficient to determine the spectroscopic factor for $1f_{5/2}$ in the ^{50}Ca ground state, as this will be much less than the 1 assumed in the gamma-ray rate estimate of Table 2. With 100 hours of beam time, and the efficiency of GRETINA, we will also be sensitive to any possible population of the 4.0 MeV $9/2^+$ state, if there is any contribution of $\nu 1g_{9/2}$ in this excited state configuration, and the ^{50}Ca ground state.

NSCL PAC 37 – 2. Status of Previous Experiments

IV. Supplemental Information (Figures, Tables, References, etc., including one figure that depicts the layout of the experimental apparatus)

References

[Ba02] D. Bazin *et al*. *Nucl. Instrum. Methods Phys. Res. A* **482**, 307 (2002).

[Br01] R. Broda, *Acta Phys. Pol. B* **32**, 2577 (2001).

[Br05] R. Broda *et al*., *Acta Phys. Pol. B* **36**, 1343 (2005).

[Cr12] H. Crawford *et al*., to be published. Based on R. Clark *et al*., NSCL E09032.

[Fo08] B. Fornal *et al*., *Phys. Rev. C* **77**, 014304 (2008).

[Ga06] A. Gade *et al*., *Phys. Rev. C* **74**, 021302R (2006).

[Ga12] A. Gallant *et al*., *arXiv:1204.1987* (2012).

[Ha99] M. Hannawald *et al*., *Phys. Rev. Lett.* **82**, 1391 (1999).

[Ho11] J. Holt *et al*., *arXiv:1009.5984v2* (2011).

[Kr08] R. Krucken, *AIP Conf. Proc.*, "Nuclear Physics and Astrophysics: From Stable Beams to Exotic Nuclei" **1072**, 52 (2008).

[Mo11] D. Montanari *et al*., *Phys. Lett. B* **697**, 288 (2011).

[Ro11] W. Rother *et al*., *Phys. Rev. Lett.* **106**, 022502 (2011).

[Sc12] A. Schwenk *et al*., private communication.

[So08] O. Sorlin *et al*., *Prog. Part. Nucl. Phys.* **61**, 602 (2008).

[Ta04] O. Tarasov and D. Bazin. *Nucl. Phys. A* **746**, 211 (2004).

[Uo94] Y. Uozumi *et al*., *Nucl. Phys. A* **576**, 123 (1994).

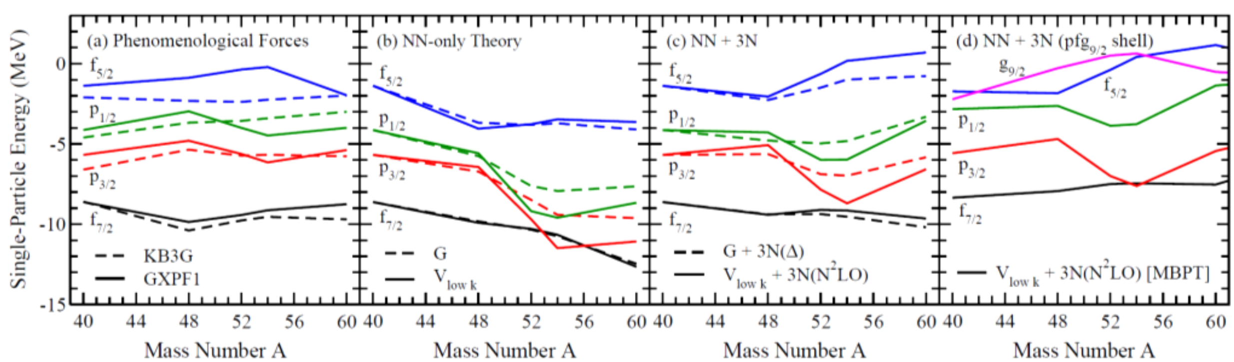

Figure 1: Neutron single-particle energy levels relative to those in ^{40}Ca, as calculated using (a) phenomenological forces, fit to data; (b) NN-only calculations; (c) NN + 3N calculations, and (d) NN + 3N calculations in an expanded model space. Taken from Reference [Ho11].

NSCL PAC 37 – 2. Status of Previous Experiments

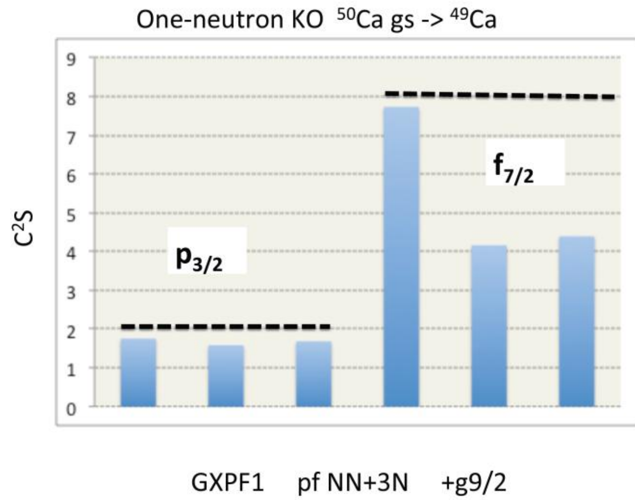

Figure 2: Spectroscopic factors calculated using the single-particle energy levels based on phenomenological forces (GXPF1), NN+3N forces restricted to the *fp*-shell, and including the $1g_{9/2}$ orbital. The reduction of the *N*=28 shell gap with the inclusion of 3N forces is expected to result in the depletion of the $1f_{7/2}$ sum rule in ^{50}Ca, and a reduced spectroscopic factor for knock-out into ^{49}Ca.

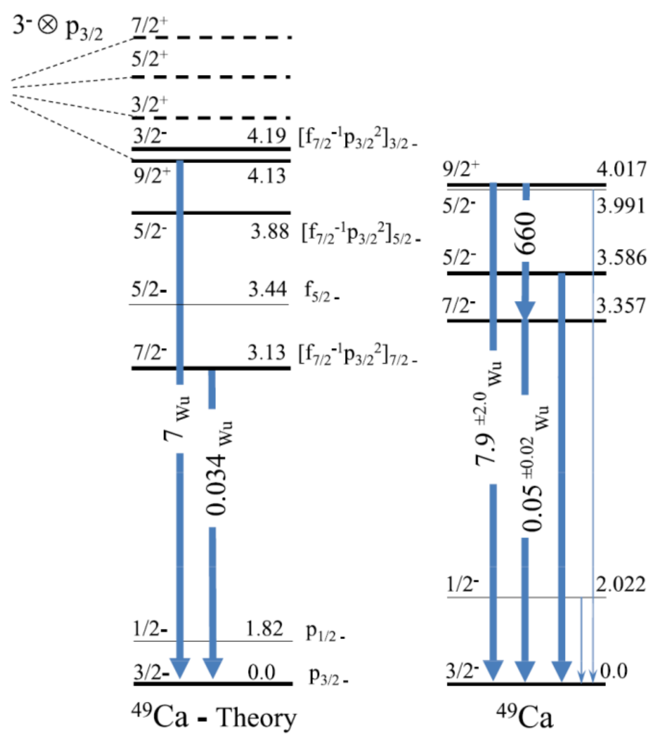

Figure 3: Level structure of ^{49}Ca from [Mo11].

NSCL PAC 37 – 2. Status of Previous Experiments

Table 1: Secondary beam production information for 4 secondary beams

Isotope	^{48}Ca	^{49}Ca	^{50}Ca
LISE++ Rate with 1% dp/p [pps/pnA]	1290	316	70.4
LISE++ Purity	92%	79%	77%
Expected Rates at A1900 Focal Plane [pps]	9030	2212	492
Rates at S800 Target [pps]	4515	1106	246

Table 2: Knockout for ^{50}Ca → ^{49}Ca, assuming the level structure of [Mo11].

E [keV]	Configuration	Expected Occupancy (C^2S)	Rate [1/hour]	Eγ (keV)	GRETINA Efficiency	Gamma Rate [1/hour]
			^{48}Ca → ^{47}Ca			
0	$1f_{7/2}^{1}$	8	34784	--	--	--
2569	$2d_{3/2}^{1}$	4	17392	2569	6%	1044
2591	$2s_{1/2}^{1}$	2	8696	2591	6%	522
			^{50}Ca → ^{49}Ca			
0	$1p_{3/2}^{1}$	1	237	--	--	--
2023.2	$1p_{1/2}^{1}$	1	237	2023.2	6.5%	15.4
3357	$[f_{7/2}^{-1}p_{3/2}^{2}]$	4 / 2 [Sc12]	948	3357	5%	47.4
3991	$1f_{5/2}^{1}$	<1	237	3991	4%	9.5 (if C^2S = 1)
4017	$3^{-} \otimes 1p_{3/2}^{1}$					

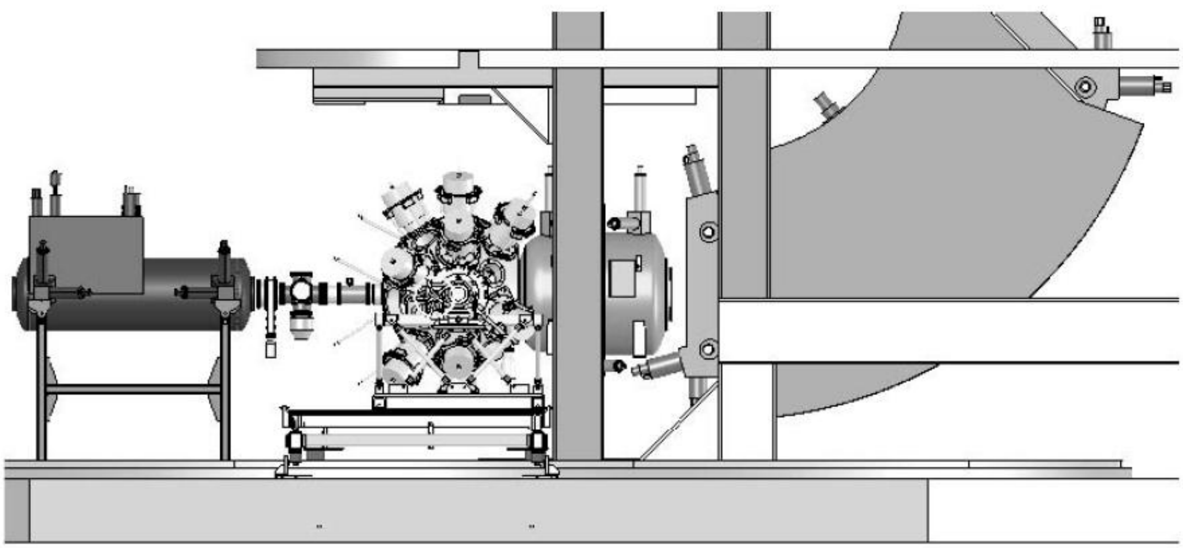

Figure 4: GRETINA at the S800

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.

E09020: Coulomb Excitation of Neutron-rich Fe and Cr (March, 2011)

- Analysis is nearly completed, publication is in preparation
- Results presented in oral contribution at Rutherford Centennial and Gamma11 international conferences

NSCL PAC 37 – 3. Educational Impact

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.

Students local to MSU/NSCL will be invited to participate in the set-up and execution of the experiment. The experiment will not be a part of any thesis work.

NSCL PAC 37 – 4. Safety Information

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: Dirk Weisshaar

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.
___________ Lifting or manipulating heavy equipment (>500 lbs)

PLEASE PROVIDE BRIEF DETAIL ABOUT EACH CHECKED ITEM.

Standard gamma-ray sources will be used for energy and efficiency calibration of GRETINA.

NSCL PAC 37 – 5. Spectrograph Worksheet

Spectrograph Worksheet for S800 Spectrograph or Sweeper Magnet

The NSCL web site contains detailed technical information and service level descriptions about the S800 Spectrograph (Service Level Description) and the Sweeper Magnet (Service Level Description).

1. Timing detectors

a) Is a plastic timing scintillator required (at the object of the S800 or in front of the sweeper magnet)?

[ ] No
[X] Yes

i. What is the desired thickness? [X] 125 μm [ ] 1 mm [ ] other _____
ii. What maximum rate is expected on this scintillator? _______ Hz

b) Do you plan to use a different type of timing detector (at the object of the S800 or in front of the sweeper magnet)?

[X] No
[ ] Yes

If "Yes," please give details.

2. Tracking detectors

Tracking detectors for incoming beam are available for Z>10. Performance limitations are to be expected at rates exceeding 200 kHz.
Are tracking detectors needed?

[ ] No
[X] Yes

3. Focal-plane rates

a) What detectors are planned to be used?
Standard FP detectors: CRDCs, Ion Chamber, Plastic Scintillator and CsI Hodoscope
b) What is the maximum rate expected in the focal-plane detection system? 1000 Hz

4. For S800 experiments only: Optics mode and rigidities:

a) Which optics mode is needed?
[ ] Dispersion matched [X] Focused [ ] Other ___________________________
b) What are the maximum and minimum rigidities planned to be used for the analysis beam line?
3.2 Tm minimum, 3.5 Tm maximum
c) What are the maximum and minimum rigidity planned to be used for the spectrograph?
2.5 Tm minimum, 2.9 Tm maximum
d) The maximum particle rate in the focal plane is 6 kHz when the CRDC detectors are being used. What is the maximum total particle rate expected in the S800 focal plane?
< 1000 Hz

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 37 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 37 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 37 – 6. Beam Request Worksheet

Beam Request Worksheet _1_ of _3_.

(Please number the sheets and use a separate sheet for each distinct beam-on-target requested.)

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope 82Se
Energy 140 MeV/nucleon
Minimum intensity 35 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 48Ca
Energy 81 MeV/nucleon
Rate at A1900 focal plane 1290 pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance 1 % (e.g. 1%, not ±0.5%)
Purity at A1900 focal plane 92 %

Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?
[ ] No
[X] Yes
What is the desired thickness? [X] 125 μm; [ ] 1000 μm
What is the maximum rate expected for this setting? _20000_Hz (1 MHz max)

Is event-by-event momentum correction from position measured at the A1900 Image 2 position required?
[X] 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): 6 hrs

Tuning time to vault: 3 hrs

Total beam preparation time for this beam: **21** **hrs**

Experimental device tuning time [see note (c) above]: 6 hrs
S800 [X]; SeGA [ ]; Sweeper [ ]; Other [X] GRETINA
On-target time excluding device tuning: 4 hrs

Total on-target time for this beam: **10** **hrs**

NSCL PAC 29 Beam Request Worksheet

Beam Request Worksheet _2_ of _3_.

(Please number the sheets and use a separate sheet for each distinct beam-on-target requested.)

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope 82Se
Energy 140 MeV/nucleon
Minimum intensity 35 particle-nanoampere (pnA)

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

Beam-On-Target

Isotope 49Ca
Energy 81.5 MeV/nucleon
Rate at A1900 focal plane 316 pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance 1 % (e.g. 1%, not ±0.5%)
Purity at A1900 focal plane 75 %

Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?
[ ] No
[X] Yes
What is the desired thickness? [X] 125 μm; [ ] 1000 μm
What is the maximum rate expected for this setting? _20000_Hz (1 MHz max)

Is event-by-event momentum correction from position measured at the A1900 Image 2 position required?
[X] 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): 6 hrs

Tuning time to vault: 3 hrs

Total beam preparation time for this beam: **9** **hrs**

Experimental device tuning time [see note (c) above]: 4 hrs
S800 [X]; SeGA [ ]; Sweeper [ ]; Other []
On-target time excluding device tuning: 24 hrs

Total on-target time for this beam: **28** **hrs**

NSCL PAC 29 Beam Request Worksheet

Beam Request Worksheet _3_ of _3_.

(Please number the sheets and use a separate sheet for each distinct beam-on-target requested.)

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope 82Se
Energy 140 MeV/nucleon
Minimum intensity 35 particle-nanoampere (pnA)

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

Beam-On-Target

Isotope 50Ca
Energy 82.5 MeV/nucleon
Rate at A1900 focal plane 70 pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance 1 % (e.g. 1%, not ±0.5%)
Purity at A1900 focal plane 75 %

Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?
[ ] No
[X] Yes
What is the desired thickness? [X] 125 μm; [ ] 1000 μm
What is the maximum rate expected for this setting? _3000_Hz (1 MHz max)

Is event-by-event momentum correction from position measured at the A1900 Image 2 position required?
[X] 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): 6 hrs

Tuning time to vault: 3 hrs

Total beam preparation time for this beam: **9** **hrs**

Experimental device tuning time [see note (c) above]: 4 hrs
S800 [X]; SeGA [ ]; Sweeper [ ]; Other [ ]
On-target time excluding device tuning: 100 hrs

Total on-target time for this beam: **104** **hrs**