National Superconducting Cyclotron Laboratory
Proposal Data Form—PAC 30

TITLE: **Single particle states in ^{56}Ni and the evolution of neutron hole states in N=28 Shell**

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

SPOKESPERSON: Jenny Lee

Address: NSCL/MSU

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BACKUP SPOKESPERSON: Betty Tsang

Institution: NSCL/MSU_

Phone: 517-333-6386 Fax: 517-353-5967 E-Mail : tsang@nscl.msu.edu

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**
O'Malley, Patrick	Rutgers (GS)	Hatarik, Robert	Rutgers (PD)
Pain, Steve	Rutgers (PD)	Jolie A. Cizewski	Rutgers
Kate Jones	University of Tennessee	Alisher Sanetullaev	NSCL (GS)
Liang, Felix	ORNL	Dan Shapira	ORNL
Bazin,Daniel	NSCL	Lynch, William	NSCL/MSU
Lee, Jenny	NSCL (GS)	Rogers, Andy	NSCL (GS)
Henzl, Vladimir	NSCL (PD)	Hanzelova, Daniela	NSCL (PD)
Desouza, Romualdo	Indiana	Hudan, Sylvie	Indiana
Famiano, Michael	Western Michigan U	Wallace, Mark	LANL
Charity, Robert	Washington U	Sobotka, Lee	Washington U
Delaunay, Franck	LPC Caen	Sergei Lobastov	Dubna
Sergei Lukyanov	Dubna		

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	58Ni	140	5	32	172
Beam 2	58Ni	35	0.1	4	52
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:	36	224

TOTAL TIME REQUEST (HOURS): ____260

NSCL PAC 30 – 3. Proposal Data Form

(Calculated as per item 4. of the Notes for PAC 30 in the Call for Proposals)

HOURS APPROVED: ________________ HOURS RESERVED: ____________________

		SET UP TIME (before start of beam)	TAKE DOWN TIME
Access to:	Experimental Vault	14 days	7 days
	Electronics Set-up Area	5 days	7 days
	Data Acquisition Computer	4 days	7 days

WHEN WILL YOUR EXPERIMENT BE READY TO RUN? 9 / 25 / 2006

DATES EXCLUDED: October 24-28, December 6-10, 2006

EXPERIMENTAL LOCATION:

___ Transfer Hall (in the A1900)
___ Transfer Hall (downstream of the A1900)
___ N3 vault (with 92" chamber)
___ N3 vault (92" chamber removed)
___ N4 vault (Gas stopping line)
___ N4 vault (Sweeper line)
___ N4 vault (User line)
___ S1 vault (Irradiation line)
___ S2 vault
_x_ S3 Vault

EXPERIMENTAL EQUIPMENT:

_x_ A1900
___ Beta Counting System
___ Beta-NMR Apparatus
___ 92" Chamber
___ Sweeper Magnet
___ Neutron Walls
___ Modular Neutron Array
___ Neutron Emission Ratio Observer
_x_ High Resolution Array
___ APEX NaI Array
___ Segmented Ge Array [ ] classic [ ] mini [ ] beta [ ] delta [ ] plunger [ ] barrel [ ] other
_x_ S800 Spectrograph [x] with [ ] without scattering chamber
___ Other (give details)

DETAIL ANY MODIFICATION TO THE STANDARD CONFIGURATION OF THE DEVICE USED, OR CHECK NONE: [x] 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:
CH_2, C, CD_2

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 30 IN THE CALL FOR PROPOSALS.

LIST ANY INTERRUPTIONS REQUIRED IN RUNNING YOUR EXPERIMENT: (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.)

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

SUMMARY (no more than 200 words):

We propose to measure the ^{56}Ni(p,d) and ^{56}Ni(d,^{3}He) reactions in inverse kinematics at E_{beam}~35 MeV/nucleon using the HiRA and the S800 spectrometer. The proposed measurement will probe the neutron and proton hole states in the "doubly" magic nucleus ^{56}Ni and yield information about the configuration of the neutrons and protons in the closed $f_{7/2}$ orbital. The knowledge about these states may resolve the apparent contradiction that N=28 closed shell seems to be

broken in the case of ^{57}Cu nucleus but seems to remain largely intact in Ni isotopes and even remains a closed shell at Z=14 for the ^{42}Si nucleus. Combined with other measurements, the proposed experiment allows the study of the evolution of the closed N=28 shell over a large range, from the double magic ^{56}Ni (N=28, Z=28) nucleus to the neutron rich ^{46}Ar (N=28, Z=18) nucleus.

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

ii. Goals of the proposed experiment

iii. Experimental Details

Physics justification

Single-particle components of the wave function are key to the reduction of complex many-body physics of nuclei to the much simpler shell model consisting of valence nucleons and an inert core. The study of these states yields information about how the shell structure evolves from stable nuclei to rare isotopes with extreme ratio of neutrons divided by protons. It is important that direct evidence obtained by measuring the configuration of the single particle or hole states is obtained. The "classic" tools to study the single particle states have been single-nucleon transfer reactions, such as (d,p) and (p,d) reactions for probing the neutron states, and the corresponding reactions such as (d,^{3}He) and (^{3}He,d) and (^{4}He,t) for probing proton states [1]. With transfer reactions, one can obtain information about the angular momentum of the orbital from the angular distributions, the excitation energy of the states and the occupancies or spectroscopic factors of the various single particle orbits.

There has been a lot of interest recently on the exact shell structure of the unstable doubly magic nucleus ^{56}Ni (N=Z=28). Recent measurement of the nuclear magnetic moment of the ground state of ^{57}Cu which could be viewed as a valence proton outside a closed ^{56}Ni core suggests significant shell breaking of N=28 in the core [2]. However, the magicity of ^{42}Si suggests that N=28 is a good closed shell [3]. To understand the evolution of the neutron single particle states outside the ^{56}Ni core, we extracted the neutron spectroscopic factors (SF) of different Ni isotopes using the angular distributions measured in the (p,d) and (d,p) reactions in the literature [4]. In this analysis, we adopted the same procedure that uses global optical potentials and the adiabatic approximation to take into account the deuteron breakup as in ref. [5]. Neutron spectroscopic factors obtained with this procedure for light nuclei with Z=3-24 are consistent with the predictions from large-basis shell model [5]. A priori, transfer reactions do not yield absolute spectroscopic factors as the analysis depends on other input parameters such as the geometry of the bound state wave-function as well as the optical potentials used in the reaction model [6]. However, if the analysis utilizes a consistent set of parameters, the absolute SF values may change depending on the optical potentials used but the relative spectroscopic factors could be determined reliably [6]. In Figure 1, the extracted SF values are compared to predictions from the large basis shell model which includes the latest T=1 effective interactions with the $f_{7/2}p_{3/2}p_{1/2}g_{9/2}$ model space [7]. The dashed line indicates perfect agreement. Except for ^{63}Ni, the experimental spectroscopic factors for the Ni isotopes are about 30% lower than the predictions from shell model. If the absolute SF values are not a concern, Figure 1 suggests that the ^{56}Ni core and the effective interactions of the valence nucleons are understood even though the results from the nuclear magnetic moment measurement for ^{57}Cu suggest otherwise [2].

To test if ^{56}Ni is a good core, the most direct way is to measure the single particle nature of the neutrons or protons in the $f_{7/2}$ orbits. Direct measurements of the spectroscopic factors of the neutron hole state in ^{56}Ni using the pickup (p,d) reaction will determine if the neutron $f_{7/2}$ orbit is indeed a closed shell. Similarly, proton spectroscopic factors in the $f_{7/2}$ orbit of the hole state in ^{56}Ni can be obtained with (d,^{3}He) reaction. If the shell is not closed, we will be able to determine the mixing configurations from the data. Such information provides constraints to the ^{56}Ni core in shell model calculations.

For N=28 isotones, the neutron spectroscopic factors for ^{48}Ca, ^{50}Ti and ^{52}Cr (Z=20, 22 and 24) have been extracted [4] and they are plotted in Figure 2. As these are stable nuclei, SF values do not depend on the protons in the $f_{7/2}$ orbit. This may change as one moves to the N=Z nucleus, ^{56}Ni (indicated by the double dashed lines on the right side of the figure) or to the more neutron rich nucleus, ^{46}Ar (indicated by the double dashed lines on the left). A proposal to measure the neutron spectroscopic factors at ^{46}Ar (Z=18) was approved in PAC29 (Expt 05133) [8]. Combined with that measurement, the current experiment will provide information on the evolution of the N=28 shell from Z=18 to Z=28. Since there is very little information about the excited states of ^{55}Ni and ^{55}Co, the data from the current experiment will provide angular momenta and other information of the excited states that are populated by the (p,d) and (d,^{3}He) reactions.

Experimental Details

Both the proton pickup ^{56}Ni(d, ^{3}He)^{55}Co and neutron pickup ^{56}Ni(p, d)^{55}Ni experiments can be performed at the same time by using a laminated target of CH_2 (1mg/cm^2) and CD_2 (0.5mg/cm^2) with the CD_2 target facing downstream. The thinner CD_2 target is necessary due to the energy and angular straggling of the outgoing ^{3}He particles. Coupled with smaller solid angle coverage and lower detection efficiencies as explained below, the rate of the experiment will be determined mainly by ^{56}Ni(d, ^{3}He) reactions.

A secondary beam of ^{56}Ni will be produced from the fragmentation of a primary beam of ^{58}Ni at 140 MeV/u, on a 730 mg/cm^2 thick Be production target, at the entrance to the A1900 separator. Based on 5 pnA ^{58}Ni primary beam, calculations using the LISE++ software indicate that a beam of ^{56}Ni at 35 MeV/u with an intensity of 400,000 pps is obtainable, employing a 435 mg/cm^2 thick Al wedge degrader at the Image 2 position of the A1900 spectrometer. Our beam purity requirement is not very stringent as we plan to track the beam particles with the MCP detectors.

The experimental setup shown in Figure 3 is similar to the setup to be used in experiment 05133. The large momentum acceptance of the S800 allows detection of both ^{55}Ni and ^{55}Cu residues with one setting. ^{3}He and d particles emitted in forward angles are detected by the high resolution array, HiRA. The HiRA consists of 20 Silicon-Silicon-CsI(Tl) telescopes, each composed of a 65 µm thick silicon strip detector, a 1.5 mm thick silicon strip detector, and a 4 cm thick CsI(Tl) scintillator read out by a PIN diode. These thicknesses are sufficient to isotopically resolve the deuterons and ^{3}He particles and stop them in the 1.5 mm Si detectors. Energetic particles that punch through both Si detectors will be vetoed by the CsI(Tl) detectors, reducing the background for particle identification. To detect the ^{3}He particles emitted in forward angles, the 20 telescopes will be arranged to reduce the forward angle gap than in the past arrangement, to cover the angular range $2° \leq \theta \leq 35°$. Due to the kinematics and forward focusing of the reaction products, this covers nearly the total solid angle in the center of mass frame. Similar setups with 16 telescopes have been used successfully last year in experiments 02018, 02019 and 02023. We will track the beam particles with two micro-channel plate detectors which were employed in Experiment 02018 and 02019 in order to obtain good angular information of the emitted ^{3}He and deuterons as well as good particle identification in the S800 to identify the heavy residues. Energy resolution of about 100 keV is expected. This is sufficient to resolve the low-lying states of ^{55}Ni and ^{55}Co.

^{58}Ni(p,d) and ^{58}Ni(d, ^{3}He) have been studied before (see e.g. [9, 10]). Degraded ^{58}Ni beam is therefore a good calibration beam for our detectors. The beam intensity is not an issue for the ^{58}Ni beam. Our estimate is that 24 hours of ^{58}Ni beam are needed to calibrate the Q-value and measure the ^{3}He and d particles resolution in our experimental setup. Due to the low beam rate of ^{56}Ni, we request 24 hours of the degraded primary beam ^{58}Ni to shake down the experimental setup including tuning the HiRA detectors. Thus for the ^{58}Ni beam degraded to 35 MeV/u, we request a total of 24+24=48 hours beam time on target. If the run is scheduled together with 05133, then we do not need the 24 hours shake-up time but we still need the 24 hours beam time for the resolution measurement.

As the count rate is mainly limited by the ^{56}Ni(d, ^{3}He) reaction. We will use this reaction to determine the beam time required. In general, all calculations suggest that the nucleon transfer cross-sections are around 1 mb/sr as shown in Figures 4 and 5 where the angular distributions of ^{56}Ni(p,d)^{55}Ni and ^{56}Ni(d, ^{3}He) reactions for ground state are plotted. The calculations were performed with TWOFNR.

We assume 400,000 pps of beam particles at the S800 scattering chamber. For the ^{56}Ni(d, ^{3}He) reactions, 2 deg in the lab corresponds to about 4 deg in the center of mass frame. To provide good resolution of the excited states, we have to minimize the energy and angle straggling in the target by using a thin 0.5 mg/cm^2 CD_2 target. Based on our experience in past analysis [6], it is important to get good data around the shoulder region in the angular distribution shown in Figure 5. This means that enough statistics should be taken at θ_{CM} =8°-10° Simulations with the HiRA detectors with the current geometry suggest an efficiency of about 0.3 in this angular range. The spectroscopic factor predicted by the independent particle model is 8. Based on the spectroscopic factor values obtained in the other Ni isotopes, we assume a reduction factor of 3. Then the calculated count rate is 1.8x10^{-4}/sec for ^{3}He at the angular region of interest and 100 counts will require about 7 days of beam time or 168 hr of ^{56}Ni beam on target. The drop in the cross-sections at larger angles is partially compensated by the increase in the efficiency of the HiRA array. Our estimate corresponds to the minimum amount of statistics needed for a reasonable measurement to obtain angular distributions in the θ_{CM}=8°-15° region. This should allow extraction of the l value as well as the SF for the ground state. If the spectroscopic factor is not reduced as much as we assume, we will have better statistics and a slight margin of safety in the measurement.

The statistics for the (p,d) reaction will be a factor of 10 more due to better efficiencies of the HiRA geometry when the peak occurs at larger angles (see figure 4). This corresponds to about 1000 counts in the peak region and 200 counts in the valley.

References

[1] M.H. Macfarlane and J.P. Schiffer, Nuclear Spectroscopy and Reactions (Academic, New York, London, 1974) Vol. 40B, pp. 170-194.

[2] K. Minamisono et al., Phys. Rev. Lett. 96, 102501 (2006)

[3] J. Fridmann et al., Nature **435**, 922 (2005).

[4] Jenny Lee, private communications.

[5] M.B. Tsang et al., Phys. Rev. Lett. 95, 222501 (2005)

[6] J. Lee et al., Phys. Rev. C 73, 044608 (2006)

[7] A. F. Lisetskiy et al., Phys. Rev. C 70, 044314 (2004)

[8] http://groups.nscl.msu.edu/hira/05133/proposal_05133.pdf

[9] F.M.Edwards et al., Nucl. Phys. A199, 463 (1973)

[10] G.Mairle et al., Nucl. Phys. A134, 180 (1969)

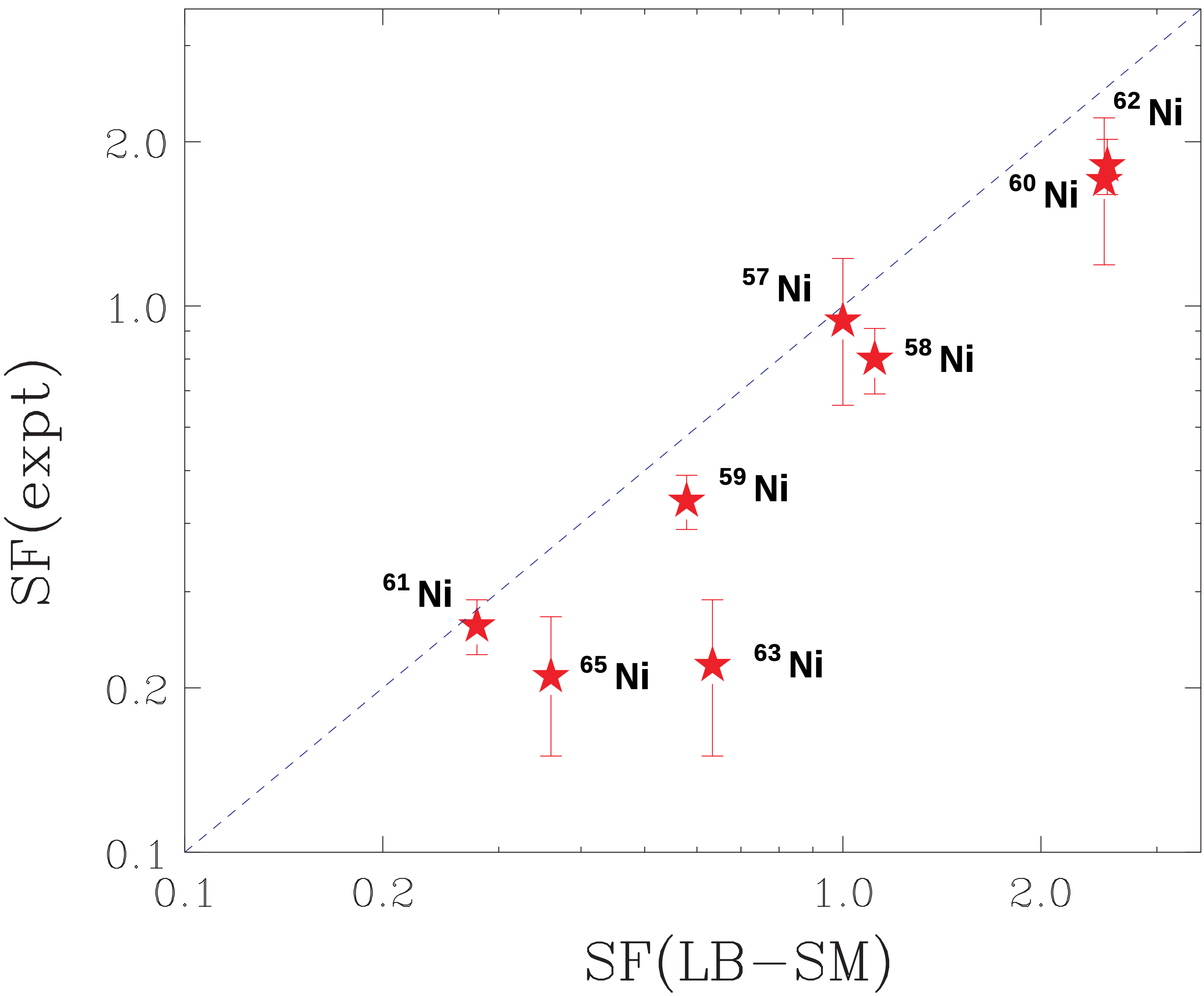

Figure 1: Comparison of spectroscopic factors to predictions from shell model for Ni isotopes using the new T=1 effective interactions and $f_{7/2}p_{3/2}p_{1/2}g_{9/2}$ model space [7]. The data are extracted from the literature [4].

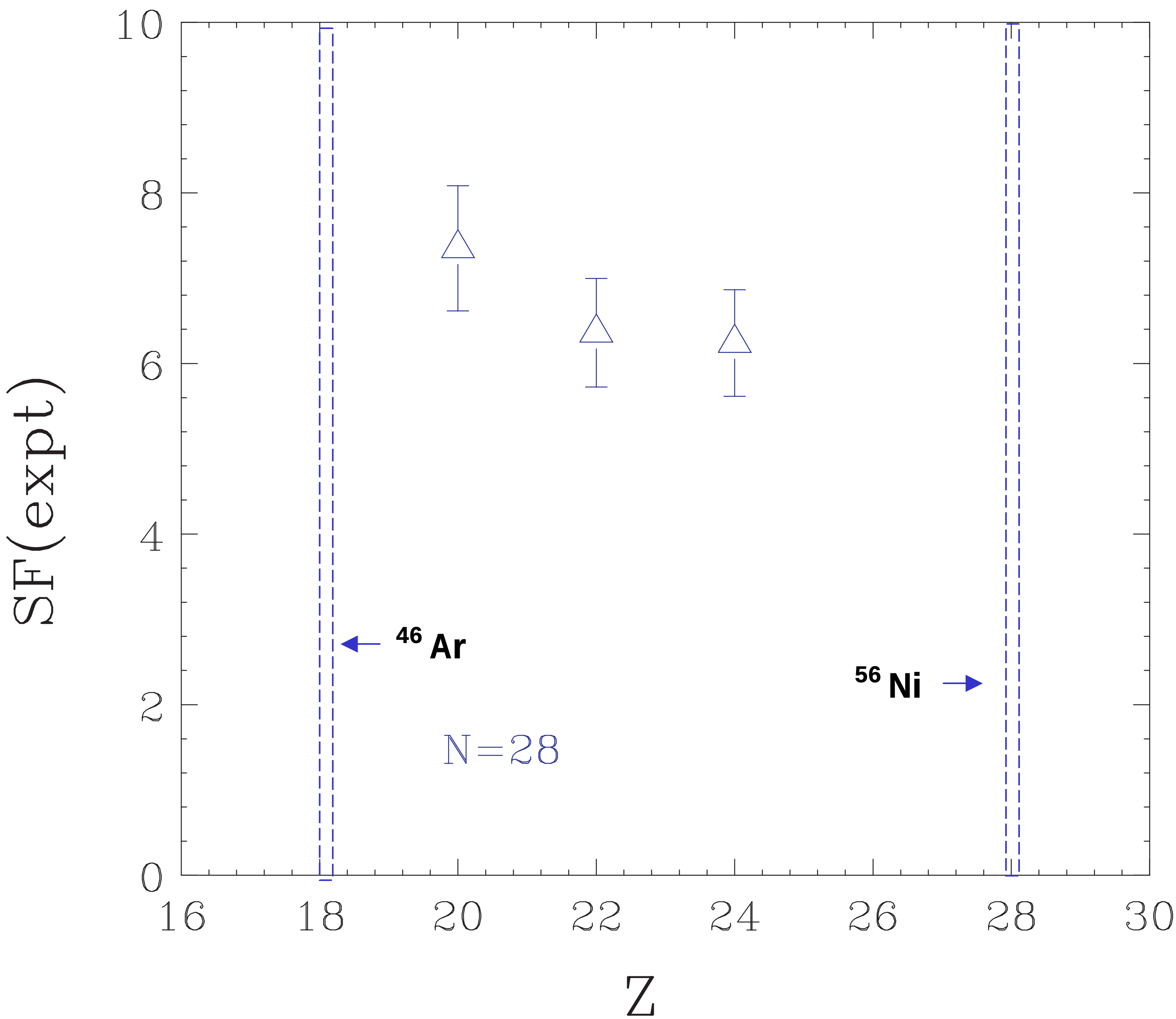

Figure 2: Spectroscopic factors for N=28 isotones. Results for the ^{46}Ar is expected from the approved experiment 05133. ^{56}Ni(p,d) reaction is the proposed measurement. Open triangles are extracted SF values obtained from the past measurements [4].

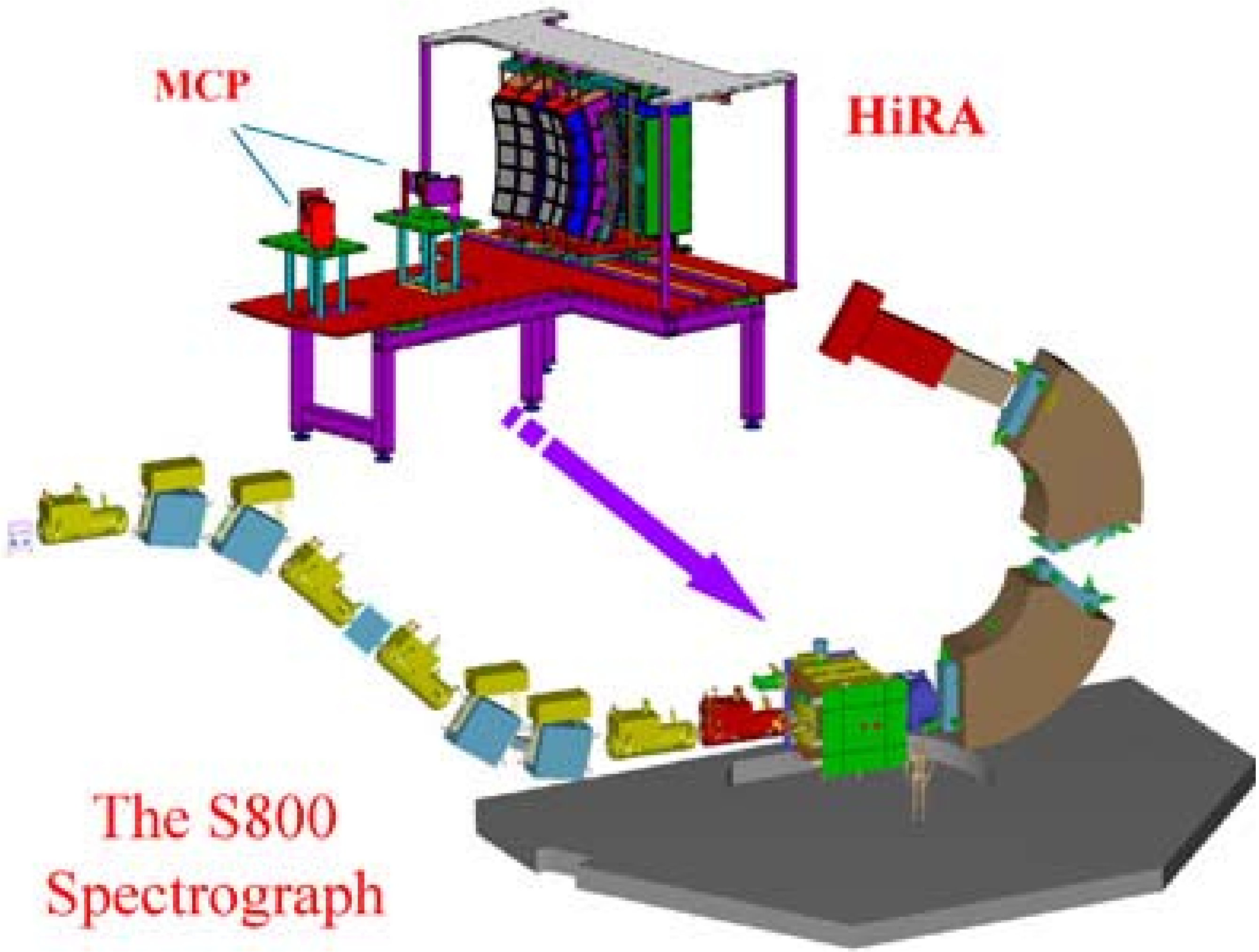

FIGURE 3: Experimental set up. The HiRA array is placed in the S800 chamber. Similar setup has been used successfully in NSCL experiments 02023, 02018 and 02019.

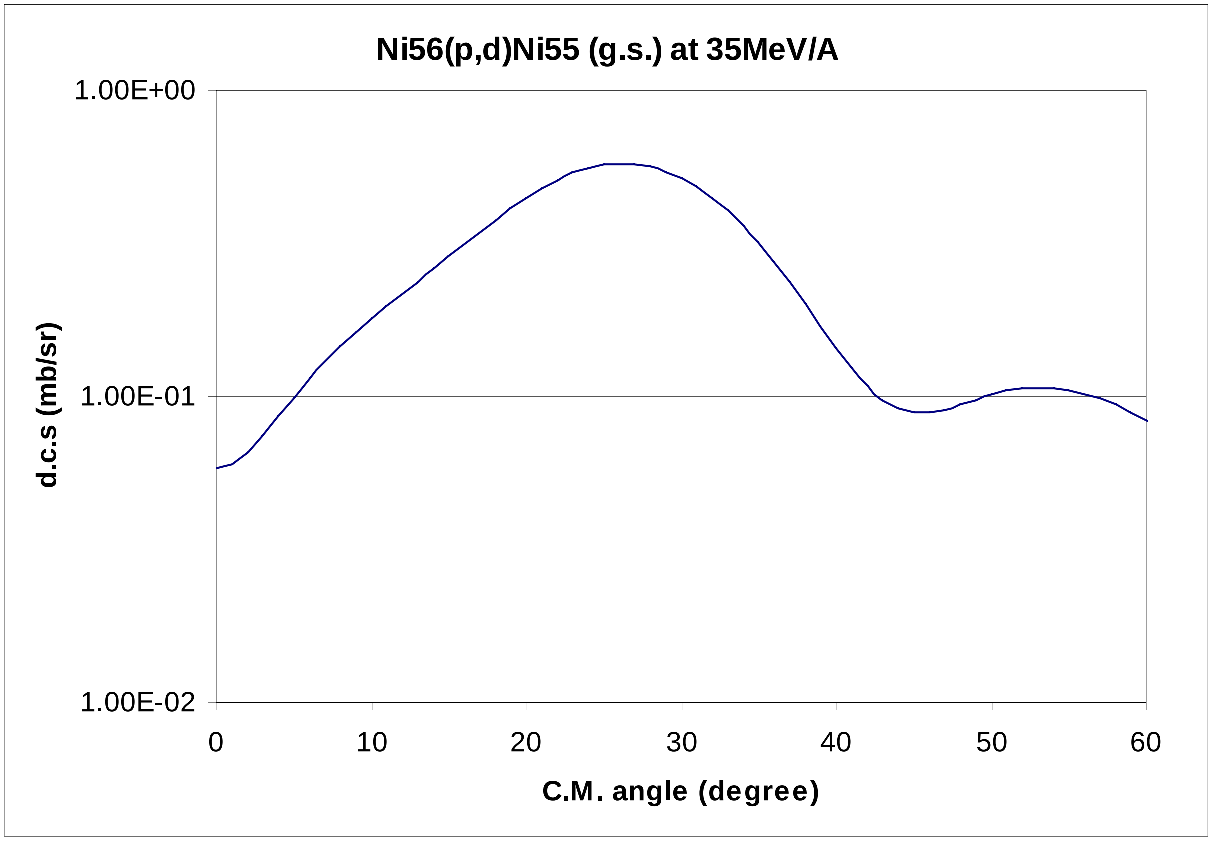

Figure 4: Angular distribution for protons emitted from the $^{56}Ni(p,d)^{55}Ni$ reaction in inverse kinematics at E=35 MeV/nucleon for transition to the ^{55}Ni ground state. The angular coverage of HiRA is >8° in the center of mass system.

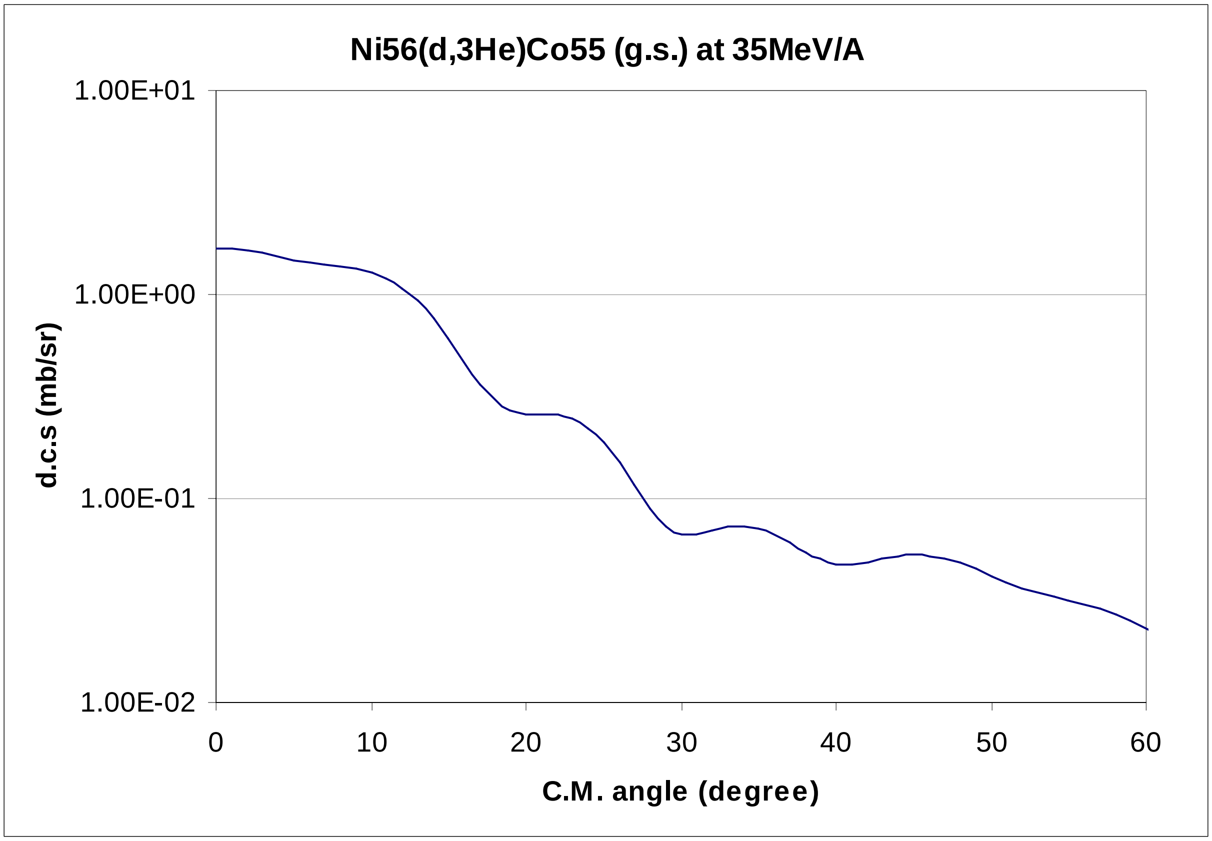

Figure 5: Angular distribution for protons emitted from the $^{56}Ni(d,3He)^{55}Co$ reaction in inverse kinematics at E=35 MeV/nucleon for transition to the ^{55}Ni ground state. The angular coverage of HiRA is >8° in the center of mass system.

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.

Experiment 01036, thesis experiment for Michal Mocko, was finished in March 2005. The fragment cross-sections from ^{48,40}Ca + Be and Ta, ^{58,64}Ni + Be, Ta reactions have been extracted. Mocko plans to defend his thesis in August. A draft of the paper is in the final stage of preparation and will be submitted for publication soon. The experimental results have been discussed in the NSCL 2005 user workshop and many international and national conferences. Experiment 03031 was run in May, 2005. The data is being finalized waiting for the simulations of the efficiencies of the S800 spectrometer. The last campaign involving HiRA for Experiment 02018, 02019, 02023 and 05038 were completed at the middle of January, 2006. Calibrations of the HiRA detectors for expt 05038 are finished. The data analysis for 02023, the thesis experiment of Andy Rogers, has started. The data of experiment 02019 is being analyzed by the Washington University group.

Two papers related to the current work have been published [5,6].

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 form part of the PhD thesis of Jenny Lee, a physics graduate student at MSU. She will be a second year graduate student and has been a research assistant at NSCL since June, 2005. She was involved with the last HiRA campaign so she is familiar with the experimental set up. She is fully involved with this proposal; she analyzed all the data and did all the calculations shown in the proposal. She should have no trouble carrying this project through.

This project would also actively engage graduate and undergraduate students, and postdocs from NSCL.

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: Betty Tsang

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.

Alpha Sources (^{228}Th) for HiRA Calibration

Spectrograph Worksheet for S800 Spectrograph and 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

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? _10^6__ Hz

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

We'll provide our own tracking detectors consisting of two MCPs

3. Focal-plane rates

a) What detectors are planned to be used? Extended focal plane.
b) What is the maximum rate expected in the focal-plane detection system? _10^6_ 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?
_2__ Tm minimum, __3.1_ Tm maximum
c) What are the maximum and minimum rigidity planned to be used for the spectrograph?
_1.7_ Tm minimum, _2.2_ 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?
_6 k _ 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 30 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 30 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, please remember to send an electronic copy of the LISE++ files used to obtain intensity estimates.

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	58Ni	
Energy	140	MeV/nucleon
Minimum intensity	5	particle-nanoampere

Tuning time (16 hrs; 0 hrs if the beam is already listed in an earlier worksheet): 16 hrs

Beam-On-Target

Isotope	56Ni	
Energy	35	MeV/nucleon
Rate at A1900 focal plane	80,000	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	1	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity	50	%
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator
	[X]	Timing start signal from A1900 extended focal plane

Delivery time per table (or 0 hrs for primary/degraded primary beam): 12 hrs

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: 32 hrs

Experimental device tuning time [see note (c) above]: 4 hrs
S800 [X] SeGA [ ] Sweeper [ ] Other [ ]
On-target time excluding device tuning: 168 hrs

Total on-target time for this beam: 172 hrs

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	58Ni			
Energy	140	MeV/nucleon		
Minimum intensity	0.1	particle-nanoampere		
Tuning time (16 hrs; 0 hrs if the beam is already listed in an earlier worksheet):			0 hrs	
Beam-On-Target				
Isotope	58Ni			
Energy	35	MeV/nucleon		
Rate at A1900 focal plane	10^6pps	pps/pnA (secondary beam) or pnA (primary beam)		
Total A1900 momentum acceptance	1	% (e.g. 1%, not ±0.5%)		
Minimum Acceptable purity	99	%		
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):			0 hrs	
Tuning time to vault:			4 hrs	
Total beam preparation time for this beam:			**4 hrs**	
Experimental device tuning time [see note (c) above]:				4 hrs
S800 [X] SeGA [ ] Sweeper [ ] Other [X] HiRA				24 hrs
On-target time excluding device tuning:				24 hrs
Total on-target time for this beam:				**52 hrs**