National Superconducting Cyclotron Laboratory
Proposal Data Form—PAC 29

TITLE: ____ ***Neutron transfer reactions for neutron rich and proton rich Ar isotopes***

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

SPOKESPERSON: __Betty Tsang____
Address: __ NSCL/MSU South Shaw Lane, East Lansing, MI___________________________
____
Phone: ___333-6386___ Fax: _____________ E-Mail : _tsang@nscl.msu.edu_____
BACKUP SPOKESPERSON: __Kate Jones ____
Institution: _____ Rutgers University _______________________
Phone: ___(865)574-6118 ___ Fax: : _____________ E-Mail : Kate@phy.ornl.gov__

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**
Lee, Jenny (GS)	NSCL	Daniel Bazin	NSCL
Sanetullaev, Alisher (GS)	NSCL	Famiano, Michael	Western Michigan University
Driscoll, Davitt (GS)	NSCL	Wallace, Mark	LANL
Rogers, Andrew (GS)	NSCL	Shapira, Dan	Oak Ridge National Laboratory
Henzl, Vladimir (PD)	NSCL	Sobotka, Lee	Washington University
Henzlova, Daniela (PD)	NSCL	Charity, Bob	Washington University
Gade, Alexander	NSCL	DeSouza, Romauldo	Indiana University
Saelim, Michael (UG)	MSU	Hudan, Silvie	Indiana University
Ragunathan, Rahul (UG)	MSU	Lukyanov, Sergey	Dubna
Bill Lynch	NSCL	Lobastov, Sergey	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 (pps)	Sum of Beam Preparation Times (Hours)	Sum of Beam-On-Target Times (Hours)
Beam 1	^{46}Ar	35	2x10^{5} pps	20	98
Beam 2	^{34}Ar	35	2x10^{5} pps	20	74
Beam 3	Mixed beams	140	2x10^{4} pps	4	14
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:	44	186

TOTAL TIME REQUEST (HOURS): ___________
(Calculated as per item 4. of the Notes for PAC 29 in the Call for Proposals)

NSCL PAC 29 – 2. Description of Experiment

HOURS APPROVED: ________________ HOURS RESERVED: ____________________

		SET UP TIME (before start of beam)	TAKE DOWN TIME
Access to:	Experimental Vault	____30____ days	____7_____ days
	Electronics Set-up Area	____7_____ days	____2_____ days
	Data Acquisition Computer	____14____ days	____2_____ days

WHEN WILL YOUR EXPERIMENT BE READY TO RUN? ______07___ / ___01___ / _____06___

DATES EXCLUDED: ____

EXPERIMENTAL LOCATION:

- ___ Transfer Hall (in the A1900)
- ___ N2 vault
- ___ N3 vault (92" chamber removed)
- ___ N4 vault (Sweeper line)
- ___ S1 vault (Irradiation line)
- _X_ S3 Vault
- ___ Transfer Hall (downstream of the A1900)
- ___ N3 vault (with 92" chamber)
- ___ N4 vault (Gas stopping line)
- ___ N4 vault (User line)
- ___ S2 vault

EXPERIMENTAL EQUIPMENT:

- _X_ A1900
- ___ 4pi Array
- ___ Neutron Walls
- ___ Neutron Emission Ratio Observer
- ___ Segmented Ge Array [ ] classic [ ] mini [ ] beta [ ] delta [ ] other
- _X_ S800 Spectrograph [X] with [ ] without scattering chamber
- ___ Other (give details)
- ___ Beta Counting System
- ___ 92" Chamber
- ___ Modular Neutron Array
- ___ Beta-NMR Apparatus
- ___ Sweeper Magnet
- _X_ High Resolution Array
- ___ APEX NaI Array

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): [X] NONE

TARGETS:

_CH_2,_Au_(For_calibration)____

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 29 IN THE CALL FOR PROPOSALS.

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

SUMMARY (no more than 200 words):

We propose to measure neutron spectroscopic factors of ^{46}Ar (neutron rich) and ^{34}Ar (proton rich) isotopes via (p,d) neutron transfer reactions at E/A=35 MeV. The experimental result will allow detail comparisons of spectroscopic factors determination using transfer reactions and nucleon knockout reactions on nuclei far from valley of stability. Furthermore, this data set will complement the large survey of neutron spectroscopic factors of isotopes near stability, and will greatly assist the development of the reaction theory of transfer reactions on nuclei far from stability.

i. Physics Justification

Transfer reactions comprise the preponderance of spectroscopic factor (SF) determinations in the literature and provide an important technique for extracting SFs for rare isotopes. However, their extracted SF's often varied widely, reflecting inconsistencies in the choice of optical potentials for the incoming and outgoing channels to which the transfer cross sections are sensitive [1,2]. Some of the difficulties in past extractions of spectroscopic factors have been associated with different parameterizations used in the reaction models, different normalizations and different assumptions used in the analysis [2]. It is not unusual to find spectroscopic factors for a particular nucleus that fluctuate by factor of 2-3. Recently, it has been shown that systematic and consistent analysis of the angular distributions for the $^{12}C(d,p)^{13}C$ and $^{13}C(p,d)^{12}C$ reactions yield the ground state spectroscopic factors to within 15% over a range of equivalent deuteron incident energy from 12 to 60 MeV [2]. A recent analysis [3] of ground state neutron spectroscopic factors from Z=3-24, using the conventional transfer reaction analysis, indicates that spectroscopic factors from (p,d) and (d,p) reactions are remarkably consistent with large-basis shell-model calculations as shown in Figure 1.

The agreement of the extracted SF factors with large-basis shell-model calculations is different from the results obtained in (e,e'p) reactions. There the proton SF values deduced from nuclei near closed shells are suppressed by about 30-40% compared to independent particle model (IPM) expectations [4]. Even though it is believed that reaction theory for (e,e'p) reactions is more exact and that electrons probe the interior of the wave functions, neutron transfers cannot be studied by electron scattering. Neither proton or neutron transfers involving exotic nuclei can be studied by electron scattering at the present time. Thus the study of single-particle properties of exotic nuclei with hadron probes remains important. Recently, quantitatively similar SF suppressions have been required to reconcile measurements of single-nucleon knockout reactions with reaction theory predictions [5]. In the past decade, nucleon knockout reactions at incident energy above 100 MeV per nucleon have been used successfully to study the single-particle structure in many nuclei [5]. However, the method has its limitations. For example, it cannot be used to study the particle unstable nuclei such as 13Be or nuclei which may decay to isotopes with isomeric states. On the other hand, transfer reactions are more general and sometimes are the only tool available to study the nuclear structure of certain nuclei even though the required beam intensity is much higher than knockout reactions. Thus, it is paramount to understand how to obtain consistent values of spectroscopic factors regardless of whether they are obtained from nucleon knock-out [5], nucleon transfer [3] or from (e,e'p) [4] reactions.

Understanding how transfer reactions for exotic nuclei should be analyzed provides an essential tool in the study of the single-nucleon properties of exotic nuclei. One interesting result from neutron knockout reactions is the observation of strong suppression (~75%) of the ground state neutron spectroscopic factor of ^{32}Ar with large neutron binding energy while nearly no suppression in SF is observed for the neutron halo nucleus ^{15}C with small neutron binding energy [5]. However, this dependence on the neutron separation energy is not evident in the transfer reaction data around nuclei at and near the valley of stability [3,7]. To cross-compare the single-particle properties obtained in transfer reactions with those obtained in nucleon knockout reactions, one must measure spectroscopic factors of neutron-rich and proton-rich nuclei obtained with transfer reactions.

ii. Goals of the proposed experiment

The survey of the ground state neutron spectroscopic factors for 80 nuclei suggests that the general features i.e. agreement with shell model predictions as shown in Fig 1, can be obtained by a well chosen chain of isotopes e.g. Ca (solid stars) [3]. As stable calcium isotopes are available within the range from ^{40}Ca to ^{48}Ca, it is difficult to produce calcium isotopes very far from stability. Aside from Ca isotopes, results from six Ar isotopes have been extracted in ref. [3]. Since our goal is to compare the neutron spectroscopic factors of a neutron rich isotope (with small n-separation energy) and a proton rich isotope (with large n-separation energy), we propose to study (p,d) transfer reactions in inverse kinematics using ^{46}Ar and ^{34}Ar isotopes. One of the reasons to choose these two isotopes is the existence of one neutron knockout results [8,9]. Suppression factor of 0.9±0.23 and 0.30±0.04 of the spectroscopic factors have been reported for ^{46}Ar and ^{34}Ar respectively. The relative suppression of the SF ~3 between the two isotopes is much larger than the accuracy of the measurements. Analysis of these reactions would lead to further theoretical development of the reaction theory for nucleon transfer and knockout reactions as described below. Furthermore, transfer reactions with nuclei far away from stability complement the study of spectroscopic factor survey of the stable nuclei.

The “conventional” analysis shown in figure 1 and described in details in ref. 3 and 7 is obtained with a three-body adiabatic model with the optical model potential CH89 [10]. The neutron wave potential assumes a Woods-Saxon potential of *fixed* radius and diffuseness parameters, r_0=1.25 fm and a_0=0.65 fm. For illustration, the solid stars in Figure 2 represent the ratios of the extracted spectroscopic factors to the shell model predictions, SF(conv)/SF(SM) for the calcium isotopes. As expected, no suppression of the spectroscopic factors is observed. However, if the neutron binding potential geometries are constrained by the Hartree Fock (HF) calculations [11] and the Jeukenne, Lejeune and Mahaux (JLM) [12] nucleon nucleus optical potentials are used, the extracted spectroscopic factors are found to be about 30% smaller than the shell model predictions. The open stars in Figure 2 represent the ratios SF(HF)/SF(SM) for the calcium isotopes. The additional data point for A=40 (open circle) is the proton SF value, as deduced from the (e,e′p) analysis of Ref. [4]. Except for ^{49}Ca, the overall suppression of the SF(HF) is similar for all calcium isotopes. (Similar conclusion is reached when the analysis is extended to most of the nuclei studied in ref. [3].) Thus as reported in past studies, even if transfer reactions may not give the absolute spectroscopic factors, the extracted relative values are accurate. It is therefore important that both neutron rich and proton rich systems are studied at the same time to observe the suppression of SF in the proton rich nucleus as reported in knockout reactions. The results from the proposed measurements analyzed with potential geometries constrained by Hartree-Fock calculations may allow better understanding of how to extract absolute spectroscopic factors from transfer reactions.

iii. Experimental Details

The scattering experiment A(p,d)B where B=A-1, will be performed in the S3 vault. The heavy reaction residues B will be detected in the S800 spectrometer and the emitted deuterons will be measured with the recently completed high resolution array (HiRA). The experimental setup in Figure 3. The HiRA consists of 20 Silicon-Silicon-CsI(Tl) telescopes, each composed of a 65 μm thick silicon strip detector (.E1), a 1.5 mm thick silicon strip detector (E2), and a 4 cm thick CsI(Tl) scintillator (E) read out by a PIN diode. These thicknesses are sufficient to isotopically resolve the deuterons 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. For this experiment the 20 telescopes will be arranged to cover 6°≤θ≤37°. Due to the kinematics and forward focusing of the reaction this covers the total solid angle in the center of mass frame. The HiRA measures the energy and angle of the deuteron created in the CH_2 target. Similar setups with 16 telescopes has been used successfully this year in experiments 02018, 02019 and 02023. We will need tracking of the beam particles in order to obtain good angular information of the emitted deuterons as well as good particle identification in the S800 to identify the heavy residue. An energy resolution of about 200 keV is expected in the center of mass. This is sufficient to resolve the first excited state of 45Ar at 0.532 MeV. For 33Ar, the first excited state is located at 1.358 MeV. Higher excited states can also be resolved.

For the first study of transfer reactions compared to knockout reactions, we want to focus in the sdf shell region where theoretical understanding of the nuclear structure by the shell model is better understood. The survey study of the transfer reactions suggests that the best incident energy range to study transfer reaction is between 10 to 40 MeV per nucleon. We request 35 MeV per nucleon ^{46}Ar and ^{34}Ar secondary beams produced from ^{48}Ca and ^{36}Ar primary beams, respectively. As the first peak in the angular distributions is mainly used in the transfer reaction analysis, we plan to measure this region well. The angular distribution of the first peak would also give us the angular momentum value of the residue.

In general, all calculations suggest that the nucleon transfer cross-sections are around 1 mb/sr as shown in Figure 4 where the angular distributions of 46Ar(p,d)45Ar for ground and first excited states are plotted. The calculations were performed with TWOFNR. The valley is about a factor of 10 lower. As we need good statistics of the peak, we aim to get 100 counts in the valley and use this as a guide for our count rate estimates. Our beam purity requirement is not very stringent. Thus we can use past beam extractions as a guide. Based on past CCF experience in tuning ^{34}Ar and ^{46}Ar beam, we can safely assume $2x10^5$ pps of beam particles at the S800 scattering chamber. (^{46}Ar has been tuned to S800 chamber and we assume 50% transmission rate from A1900 to S800 for the ^{34}Ar beam). This rate also matches well with the use of MicroChannel Plate detectors used for beam tracking. Two deg in the lab corresponds to about five deg in the center of mass frame. All the calculations show that at 35 MeV per nucleon incident energy, the minima occur within the full acceptance of HiRA, thus we can assume a solid angle of ~100 msr. If we use 2. mg/cm^2 CH_2 target, the calculated count rate is $4x10^{-4}$/sec at the valley of the distributions and 100 counts will require 70 hr of ^{46}Ar beam on target. The peak region will have about 10 times these statistics. This should allow good extraction of the l value from the angular distributions as well as the spectroscopic factor.

For ^{34}Ar, a reduction factor of 4 can be expected based on the result of ^{34}Ar studied in the knockout reactions [8]. However, this may be compensated by the increase of the cross-sections according to TWOFNR calculations using the three-body adiabatic model. Thus we request the same amount of beam time of 70 hr of ^{36}Ar beam on target.

In addition, we request 24 hours beam time to shake down the experimental setup. We also need 10 hour of mixed beams to calibrate the telescopes. Including 4 hr of S800 tuning times for each beam, we request a total of (70(46Ar)+70(36Ar)+24(shakedown)+10(tuning)+12 (S800 tuning) hr beam on target.

References:

[1] P. M. Endt, Atomic Data and Nuclear Data Tables **19,** 23 (1977)

[2] X. D. Liu, M.A. Famiano, W.G. Lynch, M.B. Tsang, J.A. Tostevin, Phys. Rev. C69, 064313 (2004).

[3] M. B. Tsang, Jenny Lee, W.G. Lynch, Phys. Rev. Lett. (in press); http://xxx.lanl.gov/ftp/nucl-ex/papers/0506/0506016.pdf.

[4] G. J. Kramer, H.P. Blok, and L. Lapikás, Nucl. Phys. **A679**, 267 (2001).

[5] A. Gade, *et al*., Phys. Rev. Lett. **93**, 042501 (2004).

[6] P. G. Hansen and J.A. Tostevin, Ann. Rev. Nucl. Part. Sci. **53,** 219 (2003).

[7] Jenny Lee, M.B. Tsang, W.G. Lynch, MSUCL1298 (2005).

[8] A. Gade, *et al*., Phys. Rev C 71 (2005) 051301(R)

[9] A. Gade, *et al*., Phys. Rev C 69 (2004) 034311

[10] R.L.Varner, W.J. Thompson, T.L. McAbee, E.J. Ludwig and T.B. Clegg, Phys. Rep. **201,** 57 (1991).

[11] B. A. Brown, Phys. Rev. C **58**, 220 (1998).

[12] J.-P. Jeukenne, A. Lejeune, and C. Mahaux, Phys. Rev. C **15**, 10 (1977); Phys. Rev. C **16**, 80 (1977).

[13] http://meetings.nscl.msu.edu/userworkshop2005/Presentations/mocko.pdf

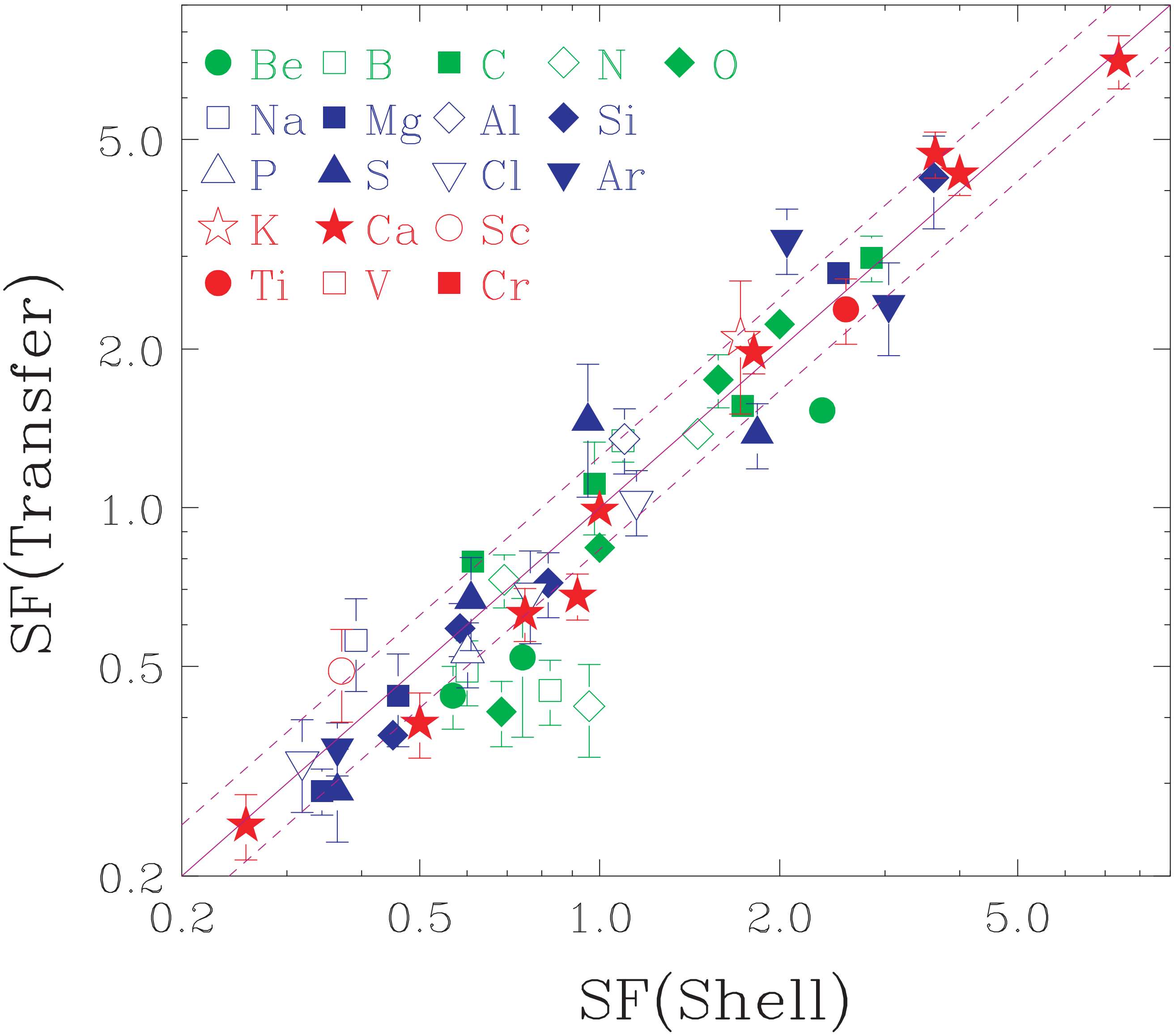
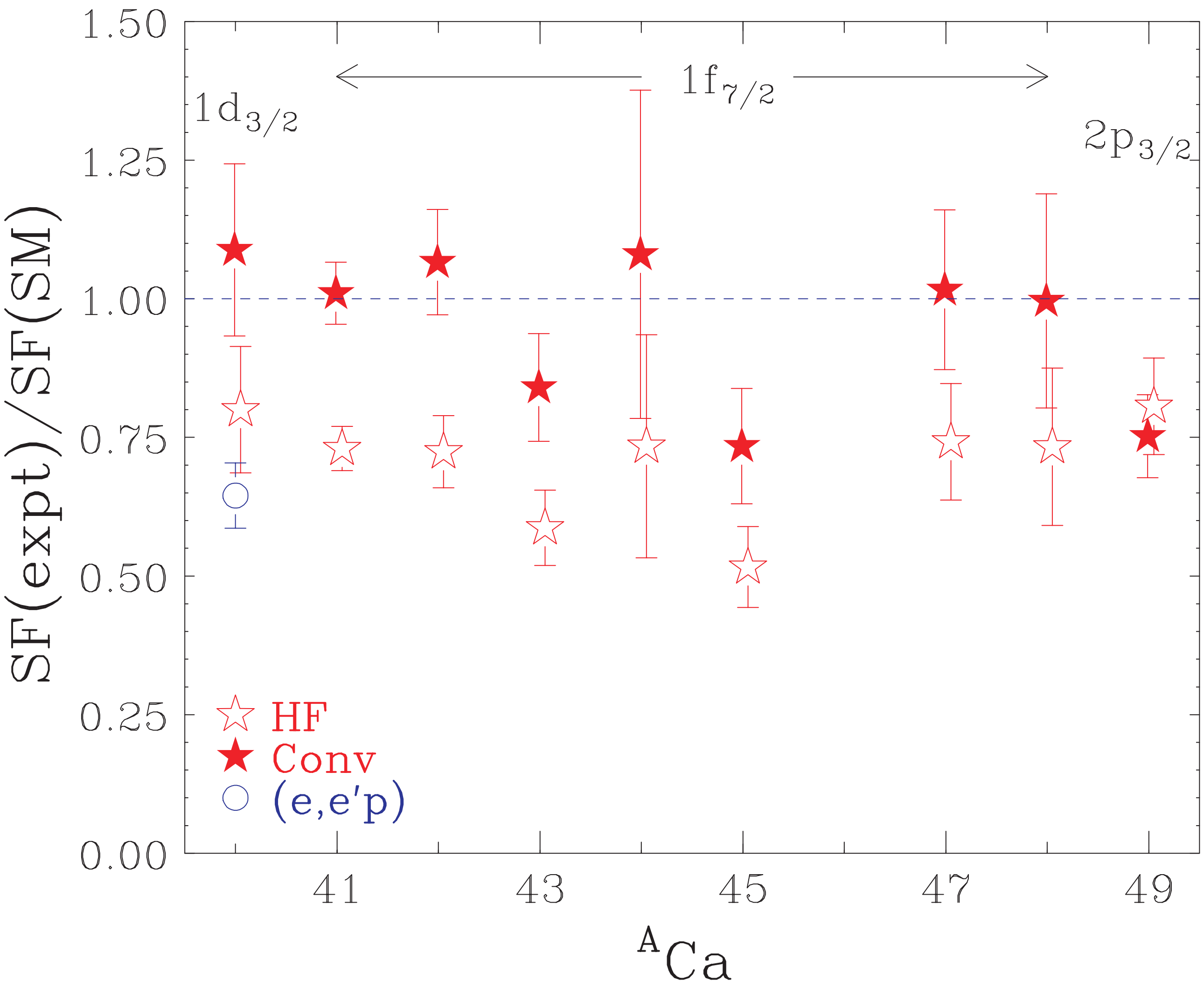


Figure 1: Comparison of experimental spectroscopic factors to predictions from the large basis shell-model calculations for isotopes from Li to Cr obtained using a conventional transfer reaction analysis. Open and closed symbols denote elements with odd and even Z respectively. The dashed lines indicate ±20% deviations from the solid line.



.

Figure 2: Ratios of the experimentally deduced spectroscopic factors to those of the shell-model SF(SM) for the calcium isotopic chain. The solid stars, SF(conv) is obtained from the use of conventional, three-body adiabatic model calculations using the Chapel Hill global nucleon optical potentials and a fixed neutron bound-state geometry (conventional analysis as in Figure 1). The open symbols, from SF(HF), are the results of constrained three-body model calculations, where both the nucleon optical potentials (the JLM microscopic optical model) and the neutron bound state potential geometry is determined by the Skyrme (SKX) Hartree-Fock calculations.

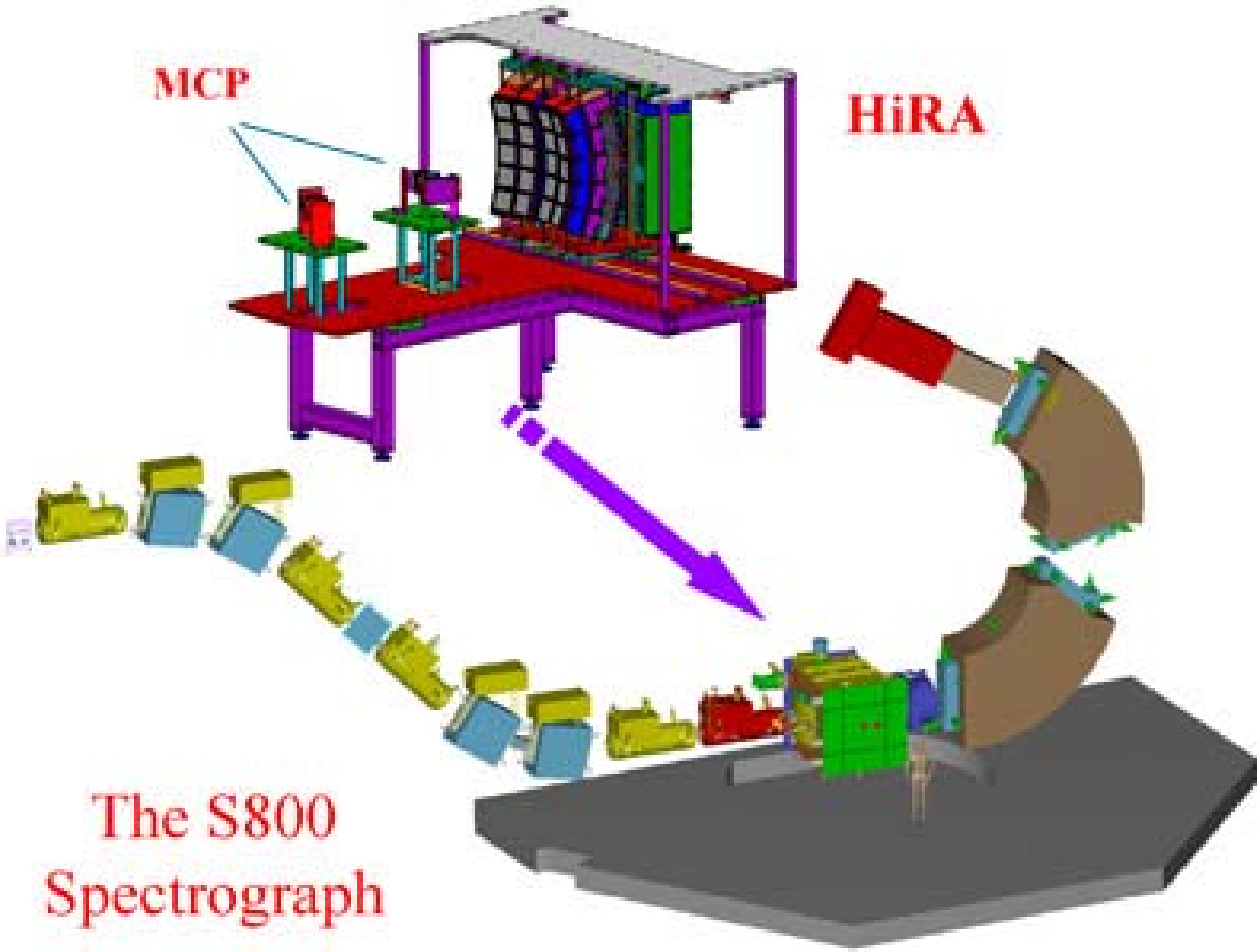
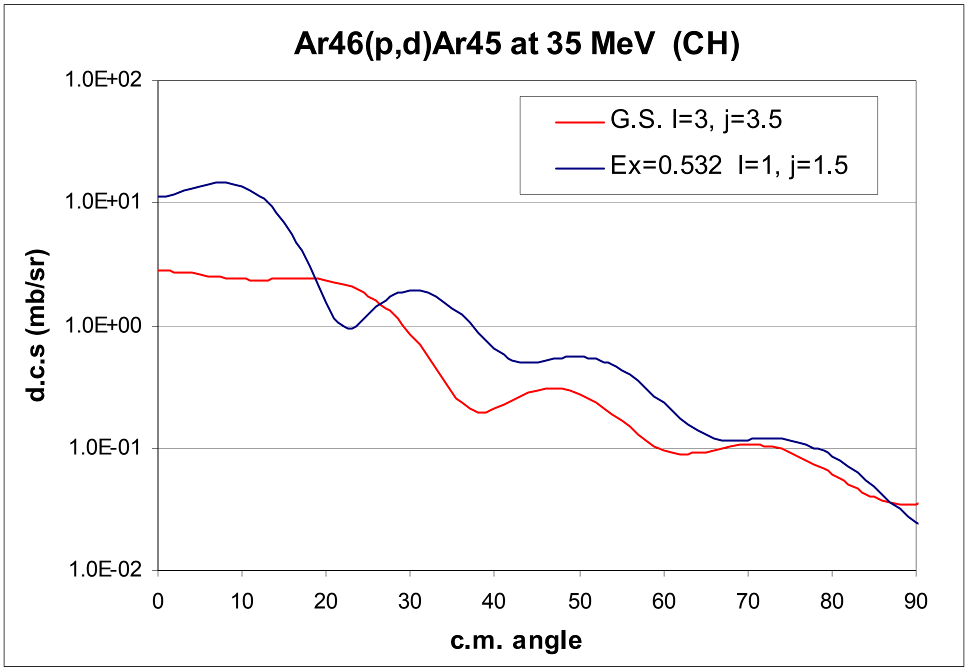


FIGURE 3: Experimental set up. The HiRA array is placed in the S800 chamber. Same setup has been used successfully in NSCL experiments 02023, 02018 and 02019.


Ar46(p,d)Ar45 at 35 MeV (CH)
G.S. l=3, j=3.5
Ex=0.532 l=1, j=1.5
d.c.s (mb/sr)
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
0
10
20
30
40
50
60
70
80
90
c.m. angle

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}Ni + Be, Ta reactions have been extracted. The cross-sections for ^{64}Ni + Be, Ta are in the final stage of data analysis. Some of the results were discussed in the NSCL 2005 user workshop [9] and are being prepared for publication.

Experiment 03031 was run in May, 2005. The data is being analyzed.

Experiment 02018, 02019 and 02023 will be completed by the end of October. Calibrations of the HiRA detectors have begun and data analysis will start at the end of the campaign at the end of October.

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 thesis for Jenny Lee, a physics graduate student at MSU. Even though Jenny is a first year graduate student, she worked on the survey of the spectroscopic factors project as an undergraduate student in the summer of 2004. She has been a research assistant at NSCL since June. She has participated in three HiRA experiments and should have no trouble carry this project through.

For the last two years, the project on the survey of spectroscopic factors has attracted many undergraduate students including two REU students and two MSU professorial assistants (Mike Saelim, Sophomore and Rahul Ragunathan, Freshman). The proposed experiment will further expose these undergraduate students to the field of experimental nuclear physics.

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):
___________ 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 29 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 29 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 1 (from beam list)

Isotope ^{48}Ca
Energy 150 MeV/nucleon
Minimum intensity 15 particle-nanoampere

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

Beam-On-Target

Isotope ^{46}Ar
Energy 35 MeV/nucleon
Rate at A1900 focal plane 13000 pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance ± 0.5 % (e.g. 1%, not ±0.5%)
Minimum Acceptable purity ____ %
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): ____ hrs

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: 20 hrs

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

Total on-target time for this beam: 98 hrs

Primary Beam 2 (from beam list)

Isotope ^{36}Ar
Energy 140 MeV/nucleon
Minimum intensity 15 particle-nanoampere

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

Beam-On-Target

Isotope ^{34}Ar
Energy 35 MeV/nucleon
Rate at A1900 focal plane 13000 pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance ± 0.5 % (e.g. 1%, not ±0.5%)
Minimum Acceptable purity ____ %
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): hrs

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: 20 hrs

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

Total on-target time for this beam: 70 hrs

Primary Beam 3 (from beam list)

Isotope: ^{36}Ar or ^{48}Ca
Energy: 140 MeV/nucleon
Minimum intensity: 15 particle-nanoampere

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

Beam-On-Target

Isotope: P,d,t, mixed beams
Energy: 35 MeV/nucleon
Rate at A1900 focal plane: 10000 pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance: ± 0.5 % (e.g. 1%, not ±0.5%)
Minimum Acceptable purity: %
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): 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 [ ]
On-target time excluding device tuning: hrs

Total on-target time for this beam: 10 hrs