National Superconducting Cyclotron Laboratory
Proposal Form—PAC 34

TITLE: Comparison of the neutron spectroscopic factors from transfer and knockout reactions at E/A=70 MeV__

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 ____

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Phone: ____ (517) 908-7356 __________ Fax: : __(517) 353-5967_

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BACKUP SPOKESPERSON: ______Betty Tsang____

Institution: _________ NSCL/ MSU____

Phone: ___ (517) 908-7386 __ 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**
Chajecki, Zbigniew	NSCL (PD)	Hudan, Silvie	Indiana U
Coupland, Dan	NSCL (SGS)	Famiano, Michael	Western Michigan U
Hodges, Rachel	NSCL (GS)	Shapira, Dan	ORNL
Iwasaki, Hironori	NSCL/MSU	Cizewski, Jolie	Rutgers U
Kilburn, Micha	NSCL (GS)	Howard, Meredith	Rutgers U (PD)
Lynch, William	NSCL/MSU	Manning, Brett	Rutgers U (GS)
Nunes, Filomena	NSCL/MSU	Merino, Enrique	Rutgers U (GS)
Pereira, Jorge	NSCL/MSU	O'Malley, Patrick	Rutgers U (GS)
Sanetullaev, Alisher	NSCL (SGS)	Jones, Kate	Univ of Tennessee
Winkelbauer, Jack	NSCL (GS)	Schmitt, Kyle	Univ of Tennessee
Youngs, Mike	NSCL (GS)	Banerjee, Kaushik	VECC, India
Charity, Robert	Washington U	Ghosh, Tilak	VECC, India
Sobotka, Lee	Washington U	Rana, Tapan Kumar	VECC, India
Desouza, Romualdo	Indiana U	Bhattacharya, Sailajananda	VECC, India

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	^{36}Ar	150	50	16	48
Beam 2	^{36}Ar	150	50	4	40
Beam 3	^{36}Ar	150	50	4	20
Beam 4	^{48}Ca	140	80	16	98

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:

40	206

TOTAL TIME REQUEST (HOURS): ___246_____
(Calculated as per item 5. of the Notes for PAC 34 in the Call for Proposals)

Access to:		SET UP TIME (before start of beam)	TAKE DOWN TIME
	Experimental Vault	____42_____ days	__14__ days
	Electronics Set-up Area	____35_____ days	__14__ days
	Data Acquisition Computer	____21_____days	__7__ days

HOURS APPROVED: ________________ HOURS RESERVED: _____________________

WHEN WILL YOUR EXPERIMENT BE READY TO RUN? _____05______ / ___01_____ / __2010_______

DATES EXCLUDED: ____

EXPERIMENTAL LOCATION:

___ Transfer Hall (in the A1900) ___ Transfer Hall (downstream of the A1900)
___ N2 vault ___ N2 vault (with Sweeper line)
___ S2 vault (Irradiation line) ___ S2 vault
_ X_ S3 vault

EXPERIMENTAL EQUIPMENT:

_ X _ A1900 ___ Beta Counting System ___ Beta-NMR Apparatus
___ Sweeper Magnet ___ Neutron Walls
___ Modular Neutron Array ___ Neutron Emission Ratio Observer
_ X _ High Resolution Array ___ 53" Chamber ___ CsI(Na) Scintillator Array
___ Segmented Ge Array [ ] classic [ ] mini [ ] beta [ ] delta [ ] barrel [ ] other
_ X _ S800 Spectrograph [X] 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: [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

REACTION TARGETS AT EXPERIMENTAL STATION:

_______CH_2,_Carbon, Au____

LIST ALL RESOURCES THAT YOU REQUEST THE NSCL TO PROVIDE FOR YOUR EXPERIMENT BEYOND THE STANDARD RESOURCES OUTLINED IN ITEM 12 OF THE NOTES FOR PAC 34 IN THE CALL FOR PROPOSALS. [ ] NONE

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

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

SUMMARY (no more than 200 words):

We propose to extract neutron spectroscopic factors of proton-rich ^{34}Ar and neutron-rich ^{46}Ar isotopes via (p,d) neutron transfer reaction in inverse kinematics at E/A=70 MeV. The neutron ground-state spectroscopic factor of ^{34}Ar obtained in a recent NSCL transfer reaction of p(^{34}Ar,d) ^{33}Ar at E/A=33 MeV (Experiment 05133) is approximately a factor of two larger than that obtained in knockout reaction at E/A=70 MeV while the neutron ground-state spectroscopic factors of ^{46}Ar are similar. The spectroscopic factors of strongly bound particles obtained from these two probes suggest a different asymmetry dependence of neutron correlations towards the drip lines. The results raise the questions about the reaction theories used to extract spectroscopic factors with these two experimental probes. The proposed measurement extends the (p,d) transfer reaction to extract the spectroscopic factors to E/A=70 MeV, a region very few reliable measurements exist. The experimental results would greatly assist in understanding the theoretical descriptions of reaction mechanism in transfer and knockout reactions.

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

Transfer reactions comprise the preponderance of spectroscopic factor (SF) determinations in the literature and provide an important technique for extracting SFs for rare isotopes. Spectroscopic factors provide information about the single particle natures of the orbital measured [1]. Information on nucleon correlations which tend to reduce the spectroscopic factors values compared to the shell model predictions can be obtained by examining how the spectroscopic factors change over a chain of isotopes or isotones.

To reduce the ambiguities in the analysis of transfer reactions, a consistent understanding of SF's from single-neutron transfer was recently achieved for (p,d) and (d,p) reactions by comparing cross-section data to calculated angular distributions from reaction models within a systematic framework. Two parameter sets have been studied extensively and form the basis of the survey of neutron spectroscopic factors from Li to Ni isotopes. Parameter set #1 uses the global nucleon-nucleus potential CH89 [2] and a fixed geometry of the bound neutrons at r_o=1.25 fm. The resulting spectroscopic factors agree with predictions from large basis shell model to 20-30%. Parameter set #2 utilizes the JLM global optical model [3] and constrains its geometry and that for the transferred-neutron bound state by Hartee-Fock calculations [4]. Parameter set #2 leads to ~30% reduction in the extracted ground state neutron spectroscopic factors compared to LB-SM predictions [5]. The reduction factor $Rs \equiv$ (experimental SF)/(theoretical SF) is similar to that observed for proton SFs obtained in (e,e'p) measurements near the closed shells, where the absolute proton SF values are systematically reduced by 30-40% compared to the Independent Particle Model [6]. However these data from both transfer and (e,e'p) reactions are limited to nuclei close to the stability.

NSCL experiment 05133 [7,8] extracted neutron transfer reactions using proton rich ^{34}Ar and neutron rich ^{46}Ar beams in inverse kinematics at E/A=33 MeV and extracted the experimental ground-state neutron SF's for ^{34}Ar and ^{46}Ar [7,8]. Within experimental uncertainties, the reduction factor for proton-rich ^{34}Ar equals to those for symmetric ^{36}Ar and for neutron-rich ^{46}Ar, shown as red circles in Figure 1. The trend is the same whether parameter set #1 (open circles) or parameter set #2 (closed circles) are used in the reaction model. In contrast, a much larger systematic suppression in SFs has been reported for the knockout reactions [9] as shown by the dashed line in Figure 1. The open triangles in the figure show that the neutron *Rs* extracted from knockout reactions for ^{34}Ar is approximately a factor of two smaller than that for ^{46}Ar. Even larger reductions are predicted for neutron knockout from ^{32}Ar, a nucleus for which transfer data is not available. This suggests that there is a systematic difference between the conclusions drawn from these two probes for the spectroscopic factors of strongly bound particles [7,8]. The recent NSCL transfer reaction result poses an intriguing question about the reaction mechanisms of transfer and knockout reactions as well as the nature of neutron correlations in nuclei with unusual isospin asymmetries [7,8].

Further work is needed to resolve the inconsistency in the exact dependence of the reduction factors on nuclear asymmetry which probes the neutron-neutron correlations towards drip lines. The projectile energies of present ^{34}Ar and ^{46}Ar SF's measurements in transfer reaction is E/A= 33 MeV but for knockout reaction, the beam energy is E/A=70 MeV. Since transfer reaction techniques allow the use of radioactive beams at both low and high incident energies, we proposed to extract the SF's of ^{34}Ar and ^{46}Ar using (p,d) transfer reaction at E/A=70 MeV, the same projectile energy as knockout reaction. The phenomenological global potentials, CH89, use data from 10 to 65 MeV and should be valid at this energy. Furthermore, the angular momentum matching is reasonable for the proposed measurements at E/A=70MeV, and is actually improved for the *l*=3 transfer compared to that at lower beam energy, which ensures the validity of simple one-step DWBA description to the data. The present experiment will allow direct comparison in spectroscopic factor determination between these two probes**.** The experimental results should help to understand whether there is energy dependence in optical potentials, which may explain the discrepancy between transfer and knockout reactions for deeply bound nuclei. Since the techniques and basic setup used in the E/A=70 MeV transfer reaction will be the same as the previous E/A=33 MeV measurement, the proposed experiment will provide a set of consistently measured transfer reaction data at high energy regime. Such data are necessary for investigating the reliability of using transfer reaction as a spectroscopic tool over a wide range of incident energies. If successful, these measurements may suggest that high *l* value transfer, which is better matched at higher incident energies, may be probed at higher incident energies where the beam intensities are higher. Previous (p,d) or (d,p) measurements at energy above 50 MeV provide poor quality data with marginal angular distributions. Thus, the present SFs survey from (p,d) reactions is limited to data with incident energy less than 40 MeV [10,11].

II. Goals of the proposed experiment

The p(^{34}Ar,d)^{33}Ar and p(^{46}Ar,d)^{45}Ar will be studied using E/A=70 MeV proton-rich ^{34}Ar and ^{46}Ar beam in inverse kinematics. This kinematically complete experiment employs the high resolution silicon array, HiRA, to detect deuterons in coincidence with the recoil residues detected in the S800 mass spectrometer. Deuteron angular distributions will be measured for the ground state and low-lying states of ^{33}Ar and ^{45}Ar. The ground-state spectroscopic factor will be extracted using parameter sets #1 and #2. Direct-comparison to the spectroscopic factors obtained in knockout reactions at the same projectile energy E/A=70 MeV would place stringent constraints on the asymmetry dependence of neutron correlations. In addition, the deduced SFs will be compared to the values obtained in a recent NSCL p(^{34}Ar,d)^{33}Ar and p(^{46}Ar,d)^{45}Ar measurement at E/A= 33 MeV. The results would be used to test the reliability of the SF's extractions in transfer reaction at different incident energy regimes. It is important to establish that transfer reactions can be used as spectroscopic tools at reasonably high energy due to the beam intensity and quality considerations in Rare Isotope Beam Facilities that use in-flight fragmentation technique to produce secondary beams.

III. Experimental Details

The proposed p(^{34}Ar,d)^{33}Ar, p(^{36}Ar,d)^{35}Ar and p(^{46}Ar,d)^{45}Ar measurement at E/A=70 MeV will be performed in the S3 vault where the High Resolution Array (HiRA), Micro-Channel Plate (MCP) and reaction targets will be accommodated in the S800 scattering chamber as shown in Figure 2. The beams will be transported and focused on the CH_2 reaction targets located in the S800 target chamber. We will use the high resolution silicon array, HiRA, to measure the energies and angles of the emitted deuterons. To ensure that the particles observed are actually the deuterons of interest, forward going recoil residues will be detected in coincidence in the S800 mass spectrometer. With the kinematically complete measurements, the coincident deuteron energies and angles could be used to identify the states populated in the final nuclei. Based on the detector performance in Experment 05133 and the Geant4 simulations, we can identify the ground-state transition.

The array of 16 HiRA telescopes will be placed 50 cm from the target where they subtended polar angles of $4° \leq \theta_{lab} \leq 40°$. The geometrical coverage and efficiency of the HiRA array setup are shown in Figure 3, where 20-25% coverage is achieved in general. Due to the forward focusing of the deuteron particles, this setup covers the total solid angle in the center of mass frame. Each telescope contains 65μm thick ΔE and 1500 μm thick E silicon strip detectors, backed by 3.9 cm thick CsI(Tl) crystals. The strips in these telescopes effectively subdivide each telescope into 1024 2mx2m pixels, each with an angular resolution of about ±0.12°. Two multi-channel plate detection systems (MCP), placed approximately 10 cm and 60 cm upstream of the target, will be employed to track the trajectories of the incoming beams. MCP is also used to monitor the average beam intensities throughout the experiment for overall normalization of deuteron cross sections.

Figure 4 shows the angular distributions of p(^{34}Ar,d) ^{33}Ar, p(^{36}Ar,d) ^{35}Ar and p(^{46}Ar,d) ^{45}Ar at E/A=70 MeV (solid curves) and E/A=33MeV (dashed curves) for ground-state transitions in laboratory frame. The calculations using the Adiabatic Distorted Wave Approximation (ADWA) were performed using parameter set # 1. The averaged cross sections in the peak regions at E/A=70 MeV are about a factor of 2 lower than that at E/A=33 MeV. The drop in cross-sections and geometric efficiencies should be compensated somewhat by the increase of beam rates as well as the improvement in beam quality and transmission at higher energies. According to LISE calculations, the beam intensities we requested are substantially larger than 1×10^6 pps. However, our experience in the previous experiments suggests that we are limited by the counting rate of the external focal plane detector (~1×10^6 pps), the MCP (5×10^5 pps) and the data acquisition system. The beam intensity will be limited to about 5×10^5 pps. We request the same number of beam hours as those used in experiment 05133. In experiment 05133, the beam on target hours were 40 hrs of ^{34}Ar, 48 hr of ^{36}Ar (including debugging) and 98 hr of ^{46}Ar beams. Longer beam time is required in the p(^{46}Ar,d) ^{45}Ar reaction due to the need to use thinner target (2 mg/cm^2) to resolve the first excited state (542 KeV) from the ground state.

We use primary beam in the reaction p(^{36}Ar,d)^{35}Ar for debugging of the experiment as well as providing a data point of SF value for the stable ^{36}Ar symmetric nucleus. The punch-through energy of deuteron in silicon detector is about 22MeV. As shown in the kinematics plot in Figure 4 (bottom-right panel), most of the deuterons in the angular range of interest will penetrate silicon detectors and stop in CsI crystals. Due to kinematic broadening and lack of abundant statistics at the backward angles, it has been very difficult to calibrate the CsI based on Q values. To calibrate CsI crystals, we request a total of 20 hour data taking of p,d mixed beams from the primary ^{36}Ar beam to elastic scatter off a ^{12}C or Au target at two energies E/A=25 and 35 MeV. The elastic scattered particle will provide calibration of the CsI detectors near the energy of the detected deuteron particles.

The experimental setup, electronics and data acquisition used in this proposed experiment is the same as those in the approved NSCL HiRA experiment 07073, Evolution of Neutron hole states in N=50 closed shells, which is scheduled to run in May, 2010. The two experiments can share debugging and calibration time if this experiment is scheduled closely behind Expt 07037 in the spirit of campaign mode, thus saving a lot of resources for NSCL and for the HiRA group.

References

[1] N. Austern, *Direct Nuclear Reaction Theories*, John Wiley & Sons, New York (1970).

[2] R.L. Varner et al., Phys. Rep. 201, 57 (1991).

[3] J.-P. Jeukenne et al., Phys. Rev. C1, 976 (1970).

[4] B. A. Brown, Phys. Rev. C58,220 (1998).

[5] Jenny Lee et al, Phys. Rev. C73, 044608 (2006).

[6] G.J. Kramer et. al., Nucl. Phys. A. 679, 267 (2001) and references therein.

[7] Jenny Lee et al., accepted by PRL, arXiv:0911.4857v1

[8] Jenny Lee, PhD thesis, Michigan State University (2009).

[9] A. Gade et al., Phys. Rev. C77, 044306 (2008) and reference therein.

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

[11] M. B. Tsang et al., Phys. Rev. Lett. 102, 062501 (2009).

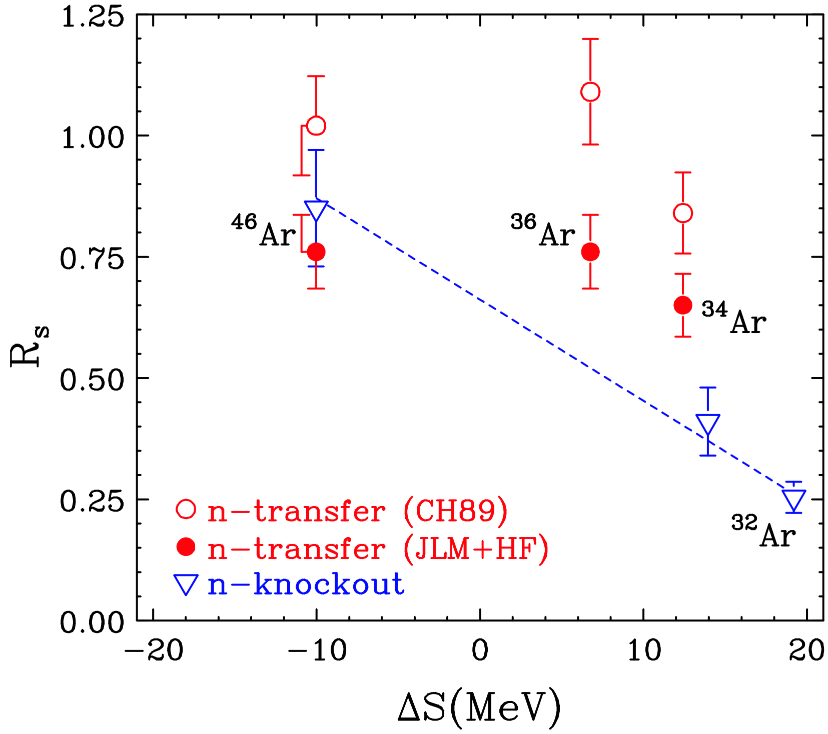

Figure 1: Reduction factors (*Rs*) as a function of the difference between neutron and proton separation energies ΔS. The open and solid circles represent the *Rs* deduced using Parameter set #1 (CH89) and Parameter set #2 (JLM+HF) respectively from transfer reaction data [7,8]. The error bars associated with the open circles reflect the uncertainties in the absolute cross-section determination. (For clarity of presentation, the error bars for the closed circles are not plotted). The open triangles denote the *Rs* from knockout reactions [9]. The ^{34}Ar ΔS values from the ref. [7,8] and ref. [9] are different. In ref. [7,8] (transfer), spectroscopic factor of the g.s. is determined while in ref. [9] (knockout), inclusive cross sections with contributions from the excited states to the ground states were measured. Thus the ^{34}Ar ΔS value in ref. [9] is weighted by the nucleon separation energy of the excited states. In principle, the knockout value should give the upper limit of the ^{34}Ar ground-state *Rs* value as contributions from excited states would increase the reduction factor. The solid line is the averaged *Rs* of ^{34,36,46}Ar from the transfer reaction data, while the dashed line is the best fit of *Rs* of ^{32,34,46}Ar from knockout reactions.

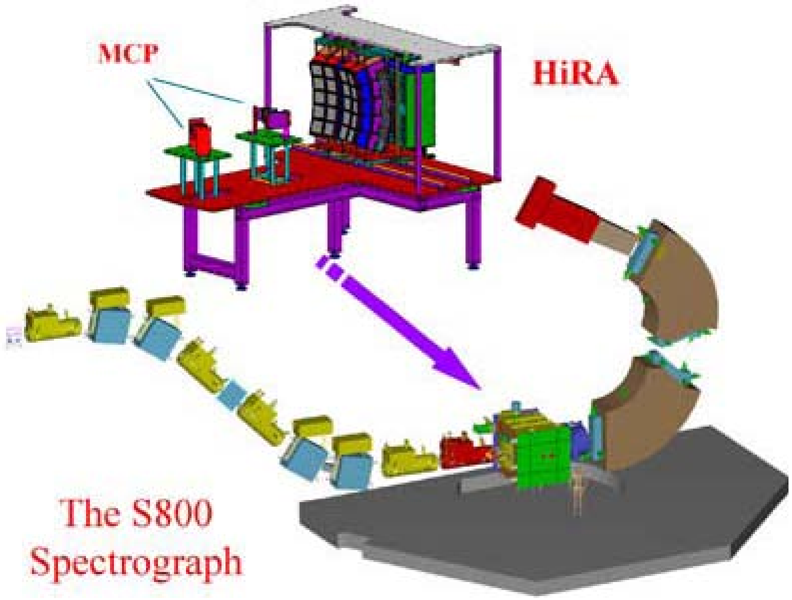

Figure 2: Experimental set up. The HiRA array and two MCP systems are placed in the S800 chamber.

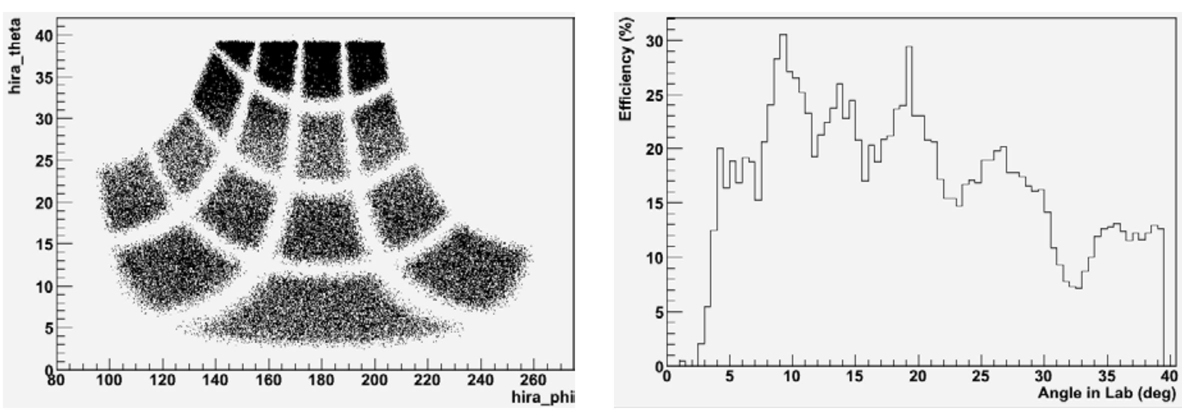

Figure 3: Efficiency of HiRA setup where 16 telescopes were placed at 50 cm from the reaction target.

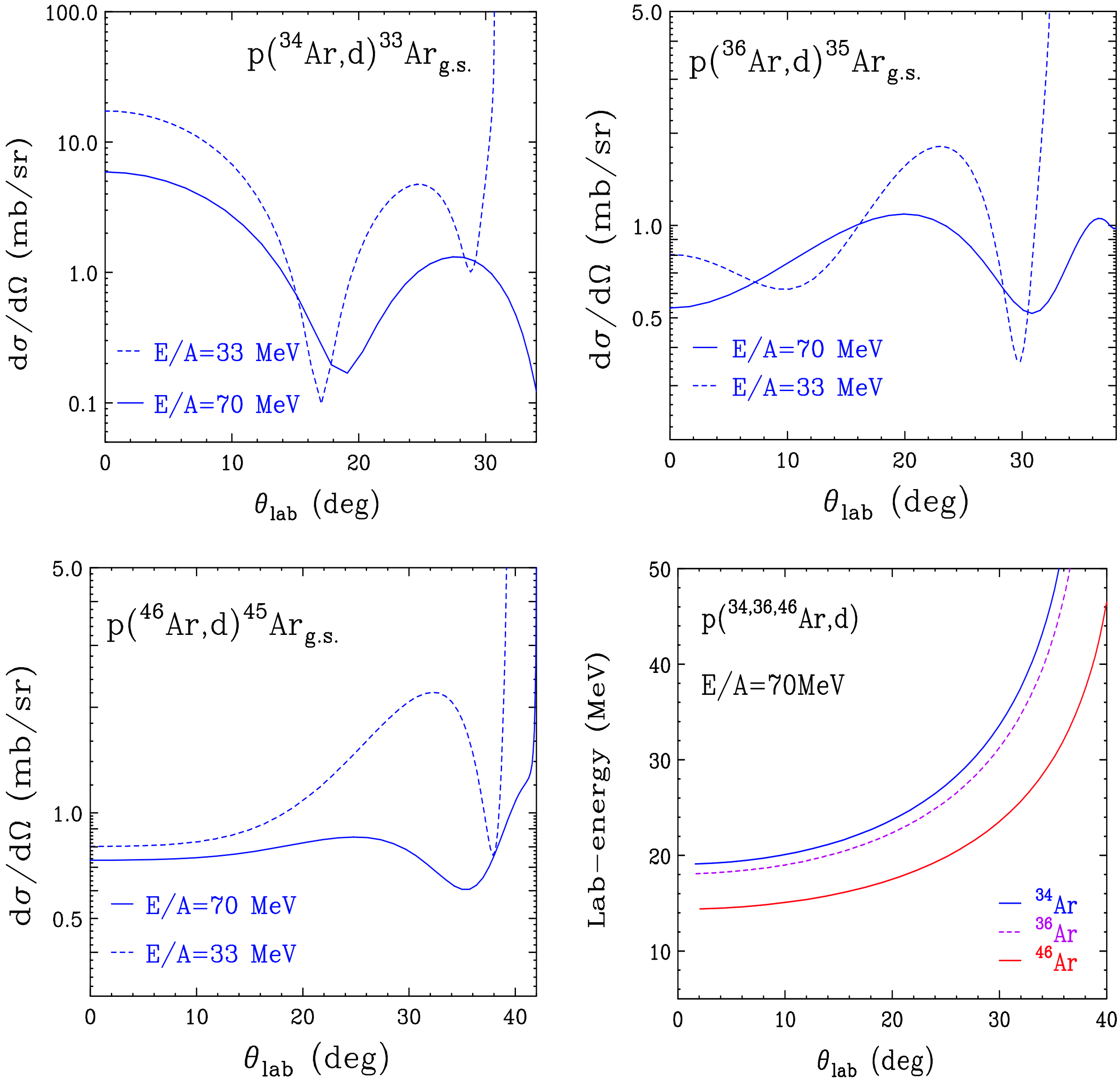

Figure 4: (Top Left) The calculated ground-state deuteron angular distributions of p(^{34}Ar,d) ^{33}Ar for ground-state transitions in laboratory frame at beam energy of E/A=33MeV (dashed line) and 70MeV (solid line). (Top Right) Same, but for p(^{36}Ar,d) ^{35}Ar reaction. (Bottom Left) Same, but for p(^{46}Ar,d) ^{45}Ar reaction. (Bottom Right) Kinematics of deuteron particles in laboratory frame at beam energy of E/A=70MeV for p(^{34,36,46}Ar,d) reactions.

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.

Three scheduled HiRA experiments:
1. Lee Sobotka (Washington University) – Expt 08001 scheduled in January 2010.
2. Jolie Cizewski (Rutgers University) -- Expt 07073 scheduled in 2010.
3. Betty Tsang (NSCL/MSU) – Expt 06035b scheduled in 2010.

Two unscheduled HiRA experiment:
1. William Lynch (NSCL/MSU) – Expt 07038, Precision Measurements of Isospin Diffusion.
2. Jolie Cizewski (Rutgers University) -- Expt 09041.

Status of previous experiments associated with Betty Tsang and Bill Lynch							
Expt number	date completed	PhD student	Year graduate	Responsible person	Presentation	Publication	Status
1032	Jun-03			M. Famiano	numerous	Phys.Rev.Lett. **97**, 052701 (2006)	
						Phys.Rev.Lett. **102**, 122701 (2009)	
1036	Jun-04	M. Mocko	2006	M. Mocko	numerous	Phys. Rev. C **74**, 054612 (2006)	
						Phys. Rev. C **76**, 067601 (2007)	
						Phys. Rev. C **76**, 041302 (2007)	
						Europhysics Letters, **79,** 12001 (2007)	
						Nucl.Phys. **A813,** 293(2008)	
						Phys. Rev. C **78**, 024612(2008)	
3031	May-05			S. Lukyanov	numerous	Phys. Rev. C **80**, 014609 (2009)	
2026	Oct-05	M.S. Wallace	2005	M.S. Wallace	numerous	NIMA **583**, 302 (2007)	
2023	Aug-05	A. Rogers	2009	A. Rogers	numerous	PhD thesis, 2009	analysis completed
						3 papers under preparation	
2019	Oct-05			R.J. Charity		Phys. Rev. C **76**, 064313 (2007)	
						Phys. Rev. C **78**, 054307 (2008)	
5038	Jan-06			D. Bazin	INPC 2007	Phys.Rev.Lett. **102**,232501 (2009)	
3045	Dec-06	M. Kilburn	2010	V. Henzl, D. Henzlova	April APS 2008	Data being analyzed	being analyzed
5133	Dec-07	Jenny Lee	2009	J. Lee	NN 2009	PhD thesis, 2009	analysis completed
					DREB 2009	Phys.Rev.Lett. accepted (2009)	
						2 more papers under preparation	
						Phys.Rev.Lett. **102**, 062501 (2009)	
						Phys. Rev. C **79**, 054611 (2009)	
06035a	Dec-07	A. Sanetullaev	2010	A. Sanetullaev		Data being analyzed	being analyzed
9042	Dec-09	M. Youngs	2012	B. Tsang		experiment scheduled	being analyzed
		D. Coupland	2011				being analyzed
8001	Jan-09			L.G. Sobotka			

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 Rachel Hodges, a first year physics graduate student at MSU. Rachel received the NSCL fellowship for her academic achievement in undergraduate. She came to NSCL in July 2009. During the summer, she became familiar with calibrations with strip detectors and CsI detectors. She has participated in a NSCL experiment 09042 using the LASSA detectors which are prototypes of the HiRA detectors. As the proposed experiment will be scheduled in May, after the Spring term finishes, she should have no trouble undertaking the proposed experiment as part of her Ph D thesis.

This project would actively engage undergraduate, REU students, graduate students and postdocs from NSCL, Rutgers University and the University of Tennessee.

This experiment is a collaborative project between NSCL HiRA group and Prof. Sailajananda Bhattacharya's group at the Variable Energy Cyclotron Centre, Kolkara, India.

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 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:

____

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 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

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

[X] No
[   ] Yes

i. What is the desired thickness? [ ] 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?

[X] No
[ ] Yes

3. Focal-plane rates

a) What detectors are planned to be used?
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?
_2.2____ Tm minimum, _3.3___ Tm maximum
c) What are the maximum and minimum rigidity planned to be used for the spectrograph?
__2.0___ Tm minimum, ___3.3__ 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?
___6k__ 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 5. of the Notes for PAC 34 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 6. of the Notes for PAC 34 in the Call for Proposals. For a non-supported device, the contact person for the device can help in making the estimate. In general, XDT is needed only once per experiment but there are exceptions, e.g. a change of optics for the S800 will require a new XDT. When in doubt, please consult the appropriate contact person.

(d) A **primary beam** can be delivered as an on-target beam for the experiment either at the full beam energy or at a reduced energy by passing it through a degrader of appropriate thickness. The process of reducing the beam energy using a degrader necessarily reduces the quality of the beam. Please use a separate worksheet for each energy request from a single primary beam.

(e) Report the Beam-On-Target **rate** in units of particles per second per particle-nanoampere (pps/pnA) for secondary beams or in units of particle-nanoampere (pnA) for primary or degraded primary beams.

(f) More information about **momentum correction** and **timing start signal** rate limits are given in the A1900 service level description.

(g) For rare-isotope beam experiments, an electronic copy of the LISE++ files used to estimate the rare-isotope beam intensity must be e-mailed to the A1900 Device Contact.

Beam Request Worksheet

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

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope ^{36}Ar
Energy 150 MeV/nucleon
Minimum intensity 50 particle-nanoampere

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

Beam-On-Target

Isotope ^{36}Ar
Energy 70 MeV/nucleon
Rate at A1900 focal plane 50 pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance 1 % (e.g. 1%, not ±0.5%)
Minimum Acceptable purity ________ %

Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?
[X] No
[ ] Yes
What is the desired thickness? [ ] 125 μm [ ] 1000 μm
What is the maximum rate expected for this setting? _________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): ____ hrs

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: 16 hrs

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

Total on-target time for this beam: 48 hrs

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope ^{36}Ar
Energy 150 MeV/nucleon
Minimum intensity 50 particle-nanoampere

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

Beam-On-Target

Isotope ^{34}Ar
Energy 70 MeV/nucleon
Rate at A1900 focal plane >2x10^{4} pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance 1 % (e.g. 1%, not ±0.5%)
Minimum Acceptable purity 75 %

Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?
[X] No
[ ] Yes
What is the desired thickness? [ ] 125 μm [ ] 1000 μm
What is the maximum rate expected for this setting? _________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): [ ] hrs

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: **4** **hrs**

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

Total on-target time for this beam: **40** **hrs**

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	^{36}Ar	
Energy	150	MeV/nucleon
Minimum intensity	50	particle-nanoampere

Tuning time (12 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	25	MeV/nucleon
Rate at A1900 focal plane	20000	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	1	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity		%

Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?

[X] No

[ ] Yes

What is the desired thickness? [ ] 125 μm [ ] 1000 μm

What is the maximum rate expected for this setting? _________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): [ ] hrs

Tuning time to vault: [2] hrs

Total beam preparation time for this beam: [2] hrs

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

S800 [ ] SeGA [ ] Sweeper [ ] Other [ ]

On-target time excluding device tuning: [ ] hrs

Total on-target time for this beam: [10] hrs

Beam Preparation Time	**Beam-On-Target Time**

Primary Beam (from beam list)

Isotope ^{36}Ar

Energy 150 MeV/nucleon
Minimum intensity 50 particle-nanoampere

Tuning time (12 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 20000 pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance 1 % (e.g. 1%, not ±0.5%)
Minimum Acceptable purity ______ %

Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?

[X] No
[ ] Yes
What is the desired thickness? [ ] 125 μm [ ] 1000 μm
What is the maximum rate expected for this setting? _________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): ____ hrs

Tuning time to vault: 2 hrs

Total beam preparation time for this beam: 2 hrs

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

Total on-target time for this beam: 10 hrs

	Beam Preparation Time	**Beam-On-Target Time**

Primary Beam (from beam list)

Isotope ^{48}Ca
Energy 140 MeV/nucleon
Minimum intensity 80 particle-nanoampere

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

Beam-On-Target

Isotope	^{46}Ar	
Energy	70	MeV/nucleon
Rate at A1900 focal plane	$>1.25\times10^4$	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	1	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity	________	%

Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?

[X] No

[ ] Yes

What is the desired thickness? [ ] 125 µm [ ] 1000 µm

What is the maximum rate expected for this setting? _________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): [ ] hrs

Tuning time to vault: [4] hrs

Total beam preparation time for this beam: [16] hrs

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

S800 [ ] SeGA [ ] Sweeper [ ] Other [ ]

On-target time excluding device tuning: [ ] hrs

Total on-target time for this beam: [98] hrs