National Superconducting Cyclotron Laboratory
Proposal Form - PAC 40

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

Title

Commissioning of the Large Charged Particle Veto Wall

Spokespeople

	Primary Spokesperson	Backup Spokesperson
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Organization	NSCL	Korea University
Position	Senior Researcher	Senior Researcher

Experimenters

Name	Organization	Position	Name	Organization	Position
Juan Manfredi	NSCL	Graduate Student	Michael Famiano	Western Michigan University	Senior Researcher
Jon Barney	NSCL	Graduate Student	John Bromell	Carleton College	Undergraduate
Justin Estee	NSCL	Graduate Student			
Suwat Tangwancharoen	NSCL	Graduate Student			
Sean Sweany	NSCL	Graduate Student			
Yan Zhang	NSCL	Graduate Student			
Pierre Morfouace	NSCL	Postdoctoral Associate			
Clementine Santamaria	NSCL	Postdoctoral Associate			
Giordano Cerizza	NSCL	Postdoctoral Associate			
Corinne Anderson	NSCL	Undergraduate			
Hananiel Setiawan	NSCL	Undergraduate			
Jerzy Lukasik	IFJ-PAN (Krakow, Poland)	Senior Researcher			
Piotr Pawlowski	IFJ-PAN (Krakow, Poland)	Senior Researcher			
Pawel Lasko	IFJ-PAN (Krakow, Poland)	Graduate Student			
Betty Tsang	NSCL	Senior Researcher			
Bill Lynch	NSCL	Senior Researcher			

Byungsik Hong	Korea University	Senior Researcher
Genie Zhang	Korea University	Graduate Student
Jung-Woo Lee	Korea University	Graduate Student
Jung-Won Lee	Korea University	Senior Researcher
Jung-Keun Ahn	Korea University	Senior Researcher
Kyong-Sei Lee	Korea University	Senior Researcher
Yong Jin Kim	IBS (Korea)	Senior Researcher
Hyo Sang Lee	IBS (Korea)	Senior Researcher
Zbigniew Chajecki	Western Michigan University	Senior Researcher

Location & Equipment Details

Location	S2 Vault
Equipment	A1900 53" Chamber High Resolution Array Neutron Walls
Additional Equipment	Large Charged Particle Veto Wall

	Setup Time (Days)	Take Down Time (Days)
Experimental Vault	30	14
Data Acquisition	30	0
Electronics	30	14

Preferred Experiment Start Date	5/1/2017
Dates Excluded	We prefer this experiment run 1 month before e14030 and e15190 in a campaign with an almost identical setup. Therefore, setup and takedown times can be shared with those two experiments.

Summary

We propose to build and commission a Large Charged Particle Veto (CPV) Wall to allow veto of charged particles in the Large Area Neutron Array (LANA). The ability to veto charged particles detected in LANA will greatly improve its effectiveness, and therefore allow for neutrons to be efficiently measured in approved experiments e14030 and e15190 (which will study heavy ion collisions to probe the nuclear equation of state). Korean collaborators will provide electronics, manpower, and expertise to help build the CPV Wall, but the wall itself will reside at the NSCL and eventually FRIB.

Special Requirements

Detail any modifications needed to the standard configuration of the device used:

The setup will be very similar to that for e14030 and e15190.

Requirements that are outside the current NSCL operating envelope:

There are no special requirements.

Reaction targets at the experimental station:

100 mg/cm^2 plastic scintillator, 5 mg/cm^2 Au

Breaks required in the schedule of the experiment:

None. We propose that this experiment run one month before e14030/e15109 to allow for evaluation of the LPV wall as well as minor changes in experimental setup.

Non-standard resources:

None.

Other special requirements:

None.

Proposal Elements

PAC40vetoWallFinal.pdf

LISE++ Files

vetoWall100deuteron.lpp
vetoWall50deuteron.lpp
vetoWall120calcium.lpp

Fast Beam Worksheet 1

Primary Beam

Beam Type	Developed
Isotope	16O
Energy	150 MeV/nucleon
Intensity	175 pnA
Tuning Time	12 hrs

Beam-On-Target

Isotope	2H
Energy	100 MeV/nucleon
Rate at Experiment	3.4e5 pps/pnA
Total A1900 Momentum Acceptance	1 %
Purity at Experiment	100 %
Rare-Isotope Delivery Time	2 hrs
Tuning Time to Vault	3 hrs
Total beam preparation time	17 hrs
Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?	No
Is event-by-event momentum correction from position measured at the A1900 Image 2 position required?	No
Experimental Device	Other - HiRA, LANA (neutron wall), veto wall
Experimental Device Tuning Time	0 hrs
On-Target Time Excluding Device Tuning	32 hrs
Total On-Target Time	32 hrs
Total Beam Preparation Time	49 hrs

Fast Beam Worksheet 2

Primary Beam

Beam Type	Developed
Isotope	16O
Energy	150 MeV/nucleon
Intensity	175 pnA
Tuning Time	0 hrs

Beam-On-Target

Isotope	2H
Energy	50 MeV/nucleon
Rate at Experiment	1.7e5 pps/pnA
Total A1900 Momentum Acceptance	1 %
Purity at Experiment	100 %
Rare-Isotope Delivery Time	2 hrs
Tuning Time to Vault	3 hrs
Total beam preparation time	5 hrs
Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?	No
Is event-by-event momentum correction from position measured at the A1900 Image 2 position required?	No
Experimental Device	Other - HiRA, LANA (neutron wall), veto wall
Experimental Device Tuning Time	0 hrs
On-Target Time Excluding Device Tuning	16 hrs
Total On-Target Time	16 hrs
Total Beam Preparation Time	21 hrs

Fast Beam Worksheet 3

Primary Beam

Beam Type	Developed
Isotope	40Ca
Energy	140 MeV/nucleon
Intensity	50 pnA
Tuning Time	12 hrs

Beam-On-Target

Isotope	40Ca
Energy	120 MeV/nucleon
Rate at Experiment	1 pnA
Total A1900 Momentum Acceptance	0.5 %
Purity at Experiment	100 %
Rare-Isotope Delivery Time	0 hrs
Tuning Time to Vault	3 hrs
Total beam preparation time	15 hrs
Is a plastic timing scintillator required at the A1900 focal plane for providing a timing start signal?	No
Is event-by-event momentum correction from position measured at the A1900 Image 2 position required?	No
Experimental Device	Other - HiRA, LANA (neutron wall), veto wall
Experimental Device Tuning Time	0 hrs
On-Target Time Excluding Device Tuning	12 hrs
Total On-Target Time	12 hrs
Total Beam Preparation Time	27 hrs

Spectrograph Worksheet

No Spectrograph Worksheet is required.

Sweeper Worksheet

No Sweeper Magnet Worksheet is required.

Safety Information Worksheet

Contact: Betty Tsang

Yes	**Radioactive sources required for checks or calibrations**	Gamma (Co and Am-Be) and neutron (Am-Be) sources.
No	**Transport or send radioactive materials to or from the NSCL**	
No	**Transport or send? to or from the NSCL?chemicals or materials that may be considered hazardous or toxic**	
No	**Generate or dispose of chemicals or materials that may be considered hazardous or toxic**	
No	**Mixed Waste (RCRA) will be generated and/or will need disposal**	
No	**Flammable compressed gases needed**	
No	**High-Voltage equipment (Non-standard equipment with > 30 Volts)**	
No	**User-supplied pressure or vacuum vessels, gas detectors**	
No	**Non-ionizing radiation sources (microwave, class III or IV lasers, etc.)**	
No	**Biohazardous materials**	
No	**Lifting or manipulating heavy equipment (>500 lbs)**	

NSCL PAC 40 PROPOSAL ELEMENTS

(all sections should be completed)

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; figures, tables and references to come at the end of the text)

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—what is to be measured; technical feasibility of measurement; count rate estimate; basis of time request; discussion of present state of readiness of the experiment and an estimated earliest date for inclusion in the run schedule; discussion of any technical assistance (design, fabrication, installation, etc.) that may be requested from NSCL;
4. Supplemental material (Figures, Tables, References, etc.). One figure must be a layout of the experimental apparatus. All graphics should be such that black-and-white copies will convey the intended information correctly; references to color should be avoided.

I. Physics Justification

The neutron/proton (n/p) emission ratio is one of the few observables to probe the symmetry energy at the high density region where the uncertainty in the asymmetry term of the equation of state remains large. The n/p ratios are also sensitive to the momentum dependence of the symmetry potential, leading to recent attempts to determine the nucleon effective masses using these ratios. The differences in the proton and neutron effective mass strongly influence the symmetry energy term in the nuclear equation of state [Mah85], the magnitude of shell effects in nuclei far from stability [Dob99, Hof01], thermal properties of core-collapse supernovae [Red99], neutron stars [Pon99], and neutron star cooling by neutrino emission [Bal14]. Recent transport calculations suggest that the sensitivity for the mass splitting lies with high energy nucleons making it necessary to detect high energy neutrons from heavy ion collisions [Zha14]. While protons and charged particles can be detected with standard charged particle detectors, neutrons are notoriously difficult to measure.

Most neutron detectors are made with scintillating materials. Detection of neutrons primarily relies on the detection of the recoiled protons when neutrons scatter off protons in the scintillators. Thus the neutron detection efficiency is low and the neutron detectors are also sensitive to charged particles, which are detected with 100% efficiency. In the case of detecting neutrons emitted in central heavy ion collisions, one needs to discriminate the neutrons of interest from gamma rays and from copiously produced charged particles. While the NSCL Large Area Neutron Array (LANA) [Zec97], which has been used to detect neutrons from several heavy ion collision experiments [Fam06, Cou13], gives excellent discrimination between neutrons and gamma rays [Zec97], it does not perform as well in removing charged particles from the neutron data [Cou13, Sho14].

To reduce the experimental uncertainties and consequently to derive tighter constraints on the symmetry energy from n/p ratios, we plan to construct a plastic-scintillator veto wall placed directly in front of LANA to remove the charged-particle contamination efficiently from the measured neutron spectrum. This veto wall method has been used successfully in the Nebula neutron wall [Neb12] at RIKEN and LAND neutron wall [Lan92] at GSI. Due to lack of resources to build a large veto wall, we used a small scintillation wall in the past, which is shown in the photo of Figure 1. The scintillator wall was placed right outside the thin walled reaction chamber, casting a geometric shadow on the neutron wall. For low multiplicity events, charged particles including protons that pass through the veto counters can be connected to the corresponding signal in the neutron wall, identifying the latter as coming from a charged particle and allowing for its rejection. Unfortunately, multiple scattering of charged particles weakens this correlation for events with very large charged particle multiplicity leading to a compromised charge particle rejection and a consequent loss of neutron detection efficiency. Figure 2 shows the identification plot of particles detected in the neutron walls in experiment 05049 after charged particle veto had been applied. The x-axis represents the calibrated time of flight in ns and the y-axis is the calibrated total pulse height in MeVee. The neutrons are visible as the smooth contribution in the spectrum. Sharp sloping lines are observed, however, for light charged particles between 50 to 100 ns. The broad sweep at low times and large pulse heights are hydrogen isotopes that punch through the neutron wall and do not deposit their full kinetic energy. Lack of precision in the removal of these remaining charged particles, which becomes more problematic at high multiplicity, is the main cause for the statistical and systematic uncertainties in the measured neutron spectra and the extracted constraints on the nucleon effective masses [Cou13]. This problem stems from the large distance that lies between the charged particle veto and the neutron wall.

Two experiments (e14030 and e15190) have been approved to study the momentum dependence of the isovector mean field potential for the $^{40,48}Ca+^{40,48}Ca$ and $^{40,48}Ca+^{112,124}Sn$ systems at 35 and 120 MeV/u Ca incident energies. To bypass the measurement of neutrons, the proposed experiments do not measure neutrons directly but will construct "pseudo" neutron spectra based on isoscaling properties of the charged fragments from Z=1 and 2 [Cha14]. While the proposed solution provides high precision ratios, it limits the energies of the pseudo-neutron spectra and n/p ratios to the highest energy/nucleon of the measured charged particles, especially tritons. The ultimate goal comparison between measured and calculated n/p ratios would include the measurement of clean high quality neutron spectra obtained by efficiently removing the charged particles detected in the neutron detectors. This would allow the n/p ratios to be further extended to much higher energies, restoring the ability to probe those high energies where the theoretical sensitivity to the effective mass splitting is its greatest.

II. Goals of the proposed experiment

We propose to build and commission the large plastic Charged Particle Veto wall (CPV) to allow veto of charged particles in the Large Area Neutron Array (LANA). Our Korean collaborators (who also collaborate in e14030 and e15190) are currently building a neutron array with a veto wall, as part of the Large Acceptance Multipurpose Spectrometer (LAMPS) at the rare-isotope beam facility RAON in Korea. Until beam is available in RAON, they will loan us their electronics for the CPV. In addition, the Korean collaboration will provide manpower to help with construction of the CPV. After commissioning, the CPV will remain at the NSCL and will be part of the detectors in FRIB when it comes on line.

We aim to complete the construction of the veto wall by the summer of 2017. In addition to requesting beam time to commission the veto wall, we would like beam time to calibrate both the neutron wall and the veto wall so that it can be used in the first series of experiments with the upgraded High Resolution Array (HiRA) to probe the nucleon effective mass splitting (e14030 and e15190). Measurements of high quality neutron spectra will enhance the physics of those two experiments to determine the nucleon effective mass splitting using the n/p ratios from $^{40,48}Ca$ induced reactions on $^{40,48}Ca$ and $^{112,124}Sn$ targets.

III. Experimental Details

Figure 3 shows the schematic of one of the LANA walls, which consist of 25 Pyrex glass tubes filled with the liquid scintillator NE-213. Each Pyrex cell is 2 m in length, 7.62 cm in height and 6.35 cm in depth. The cell wall is 3 mm thick. The total height of the wall is 2 m. The CPV will be placed in front of LANA and will consist of 25 1-cm thick horizontal plastic scintillators bars matching the geometry of the Pyrex glass tubes in LANA to minimize any ambiguities in matching signals from the CPV and LANA. A schematic diagram of the CPV and LANA is shown in Figure 4. The hit position in individual wall tubes and veto bars will be determined using the time difference between light signals measured in the tubes on opposite ends of the scintillation bars.

Figure 5 shows the experimental setup. The proposed setup inside the reaction chamber uses the same HiRA detectors as those used for NSCL experiment e15190. In the commissioning runs, HiRA telescopes will be placed at more forward angles. The neutron walls are placed on the opposite side of the beam as the HiRA array with a similar angular coverage of roughly 5^0 – 30^0. We propose to use protons from the elastic scattering of 50 and 100 AMeV deuteron beams on a thick CH_2 target (d+p reaction) to calibrate the neutron wall and the new veto wall. To provide the TOF for the veto and neutron wall, we will use a 1-mm plastic scintillator as target. Figure 6 shows the kinematics of the elastic scattering of deuteron particles, the recoil proton particles and their correlated angles for beam energy of 50 (blue) and 100 (red) MeV per nucleon. The elastic scattered deuteron will be detected in the HiRA array with an angular resolution of 0.32^0 and an energy resolution of about 250 keV. The energy and angle of the outgoing protons detected in the veto and neutron walls can be determined from complete kinematics. In addition to an energy calibration, this method also provides complementary position calibrations of the wall tubes and veto bars.

Due to its weak binding, the deuteron breaks up easily into a neutron and a proton. Figure 7 shows the kinematics of neutrons from d breakup for 100 (upper red curve) and 50 (lower blue curve) MeV per nucleon incident energy. Since there are 4 energy points, efficiency as a function of electronic threshold can be determined. Background and scattering effects will also be measured. Protons have similar kinematics and can be distinguished from the neutrons using the veto wall. Thus, measurement of the neutrons and protons in LANA with the veto wall from the breakup of deuteron beam provides a rigorous test to determine the performance of the veto wall as a charged particle veto and its effect on neutron detection.

For a count rate estimate, we use the breakup cross-section as the rate determining reaction. The breakup cross-section of d on a ^{12}C target at 28 MeV/u has been measured [Mat80] at 9.5 degrees. Compilation of d break-up data suggests that the total cross-sections do not increase drastically beyond 10 MeV/u incident energy [Avr11]. We take the cross-sections at 9.5 deg to be 500 mb/sr as calculated by Brett Carlson [Car15, Car16] whose calculations also reproduce the experimental values of ref. [Avr11]. The beam intensity for 50 MeV/u deuterons is 9.5E4 pps (from LISE++ and from a past A1900 run for e07018). We will use a 1 mm (~100 mg/cm2) thick scintillator, which also provides the start time for the neutron TOF measurement. Taking into account the solid angle of a 20 cm x 7 cm section of the neutron wall and the neutron detection efficiency of 10%, we will have 200 counts from the breakup neutrons after 16 hours of run time. We should be able to trace the break up kinematic points of the neutrons to about 12 deg. Since protons will be ten times more abundant than neutrons, we will be able to evaluate the efficiency of the veto wall in vetoing protons and observe the effect of the veto on the neutron spectra.

The ultimate success is to produce a LANA particle ID plot (as in Figure 2) without all the charged particles when the veto wall is applied. Thus, we request 8 hours of Ca beam on a 5 mg/cm^2 Au target to generate both neutron and charged particles emitted in heavy ion collisions so that we can analyze the data offline to determine the rejection percentage of charged particles. This can be accomplished by plotting the LANA particle ID with and without rejection of charged particles from the veto wall. We will use the same beam, 120 MeV/u ^{40}Ca, as in e14030 and e15190 so that most of the beam development time from those experiments can be used to produce the Ca beam. In that case, we do not need to request tuning beam time even though it is included in the proposal as required.

In summary we request 16 hours of a deuteron beam at 100 MeV/u to commission the veto wall with the new Korean electronics, to check the veto performance with the neutron wall, to set up part of the HiRA array, and to verify the electronic timing, 16 hours for calibration of the veto and neutron walls, 16 hours of a 50 MeV/u deuteron beam for a second calibration point, and 8 hours of a 120 MeV/u ^{40}Ca beam to evaluate the performance of the veto wall in a real heavy ion reaction environment. Including the 17 hours of beam preparation for the 100 MeV/u deuteron beam, another 5 hours for the 50 MeV/u deuteron beam, and 15 hours for the 120 MeV/u ^{40}Ca

beam, our total beam time request is 97 hours (see Table 1). If this experiment runs in a campaign with e14030 and e15190, the beam preparation time for the heavy ion beam could be combined with the time already approved for e14030. We should be ready to commission the veto wall in the spring of 2017 after we finish construction and initial testing of the wall with cosmic rays. We would like to have the experiment scheduled about one month before the campaign of e14030 and e15190 so that the veto and neutron walls can be incorporated into those experiments after commissioning. We need the time in between to reconfigure the HiRA telescopes and the neutron wall to the actual experimental configuration.

References:

[Avr11] M. Avrigeanu and V. Avrigeanu, Journal of the Korean Physical Society, Vol 59, 903 (2011).
[Bal14] M. Baldo, G. F. Burgio, H.-J. Schulze, and G. Taranto, Phys. Rev. C **89**, 048801 (2014).
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[Mah85] C. Mahaux, P. F. Bortignon, R. A. Broglia, and C. H. Dasso, Physics Reports **120**, 1 (1985). [Mat80] Matsuoka et al., NPA345, 1 (1980).
[Pon99] J. Pons, S. Reddy, M. Prakash, J. Lattimer, and J. Miralles, Astrophys. J. **513**, 780 (1999).
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[Zec97] P. D. Zecher, A. Galonsky, J. J. Kruse, S. J. Gaff, J. Ottarson, J. Wang, F. Deak, A. Horvath, A. Kiss, Z. Seres, et al., Nucl. Instrum. Meth. A **401**, 329 (1997).
[Zha14] Yingxun Zhang, M.B.Tsang, Zhuxia Li, and Hang Liu, Phys. Lett. B 732, 186 (2014).

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

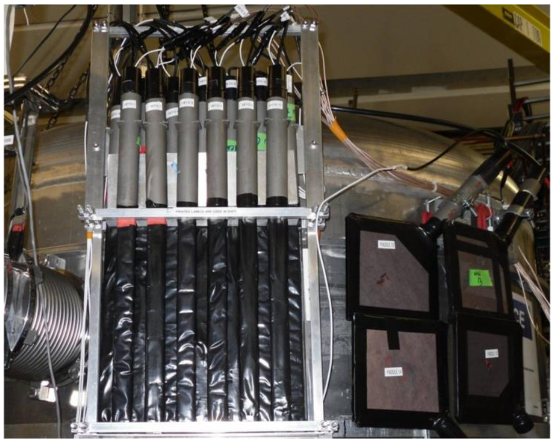

Figure 1: Charged particle veto walls used in e09042 [Cou13]. The scintillator array on the left shadowed the forward LANA wall while the paddles on the right formed the veto wall for the backward LANA wall.

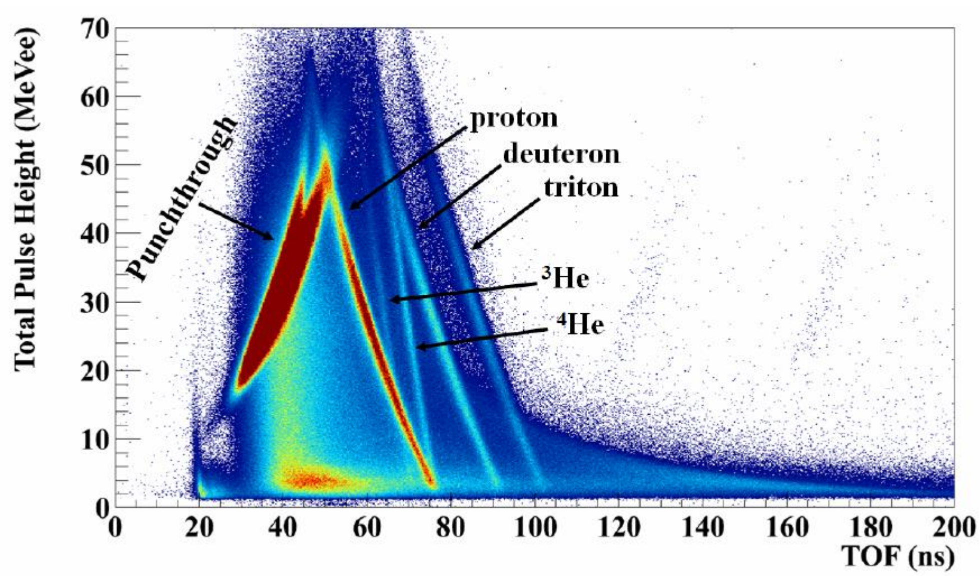

Figure 2: Particle ID plot in LANA after applying veto counter shown in Figure 1 [Sho14]. The neutrons are visible across the spectrum. The sharp slanted lines are charged particles which were not completely vetoed. The intense sweep of counts between 30 to 50 ns and 15 to 50 MeVee are the hydrogen isotopes that punch through the neutron detectors and thus do not deposit their full kinetic energy. The veto wall will allow one to measure similar spectra, but without the large contamination from charged particles.

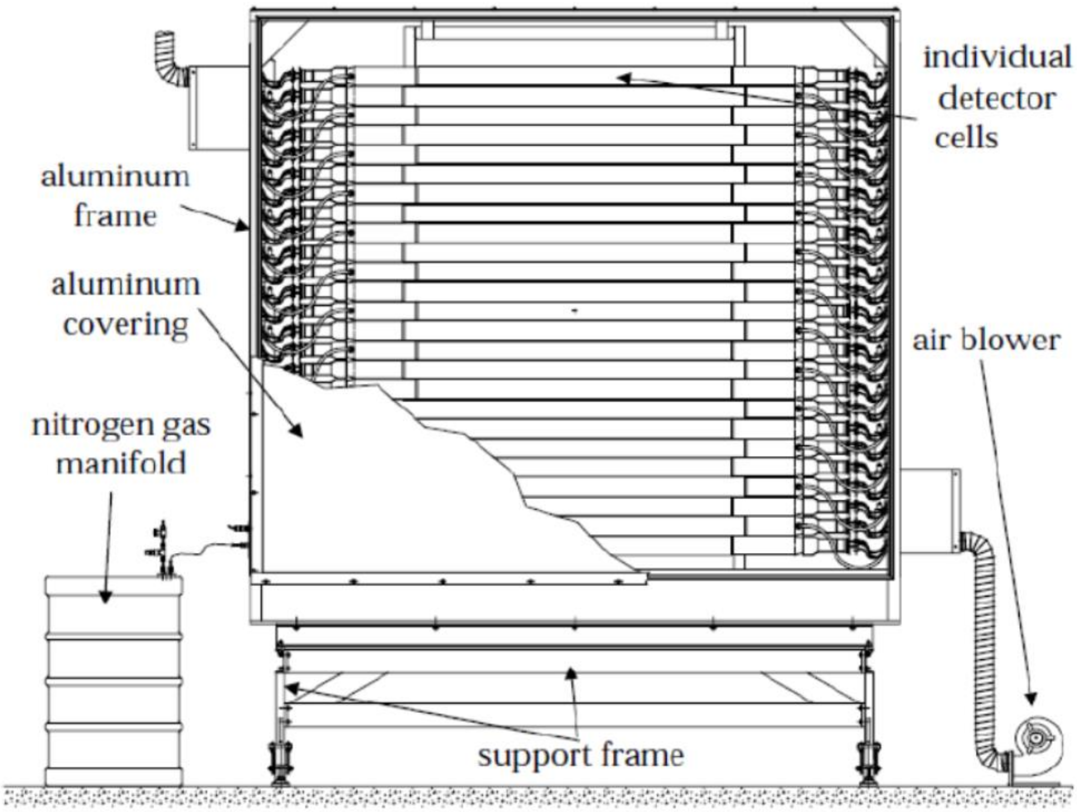

Figure 3: A schematic of the inside of the NSCL Large Area Neutron Array (LANA) [Zec97]

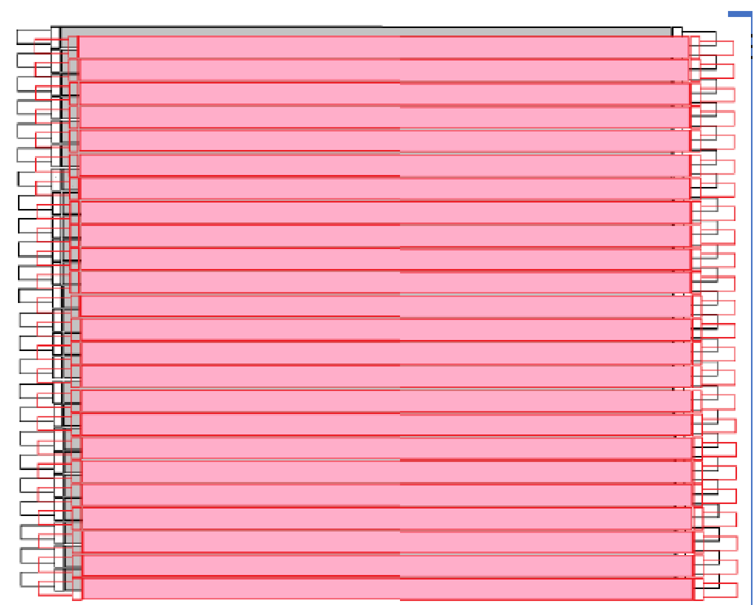

Figure 4: A schematic of the geometry of the veto wall (shaded pink). The veto wall is offset a little to show the LANA wall (in black) behind it.

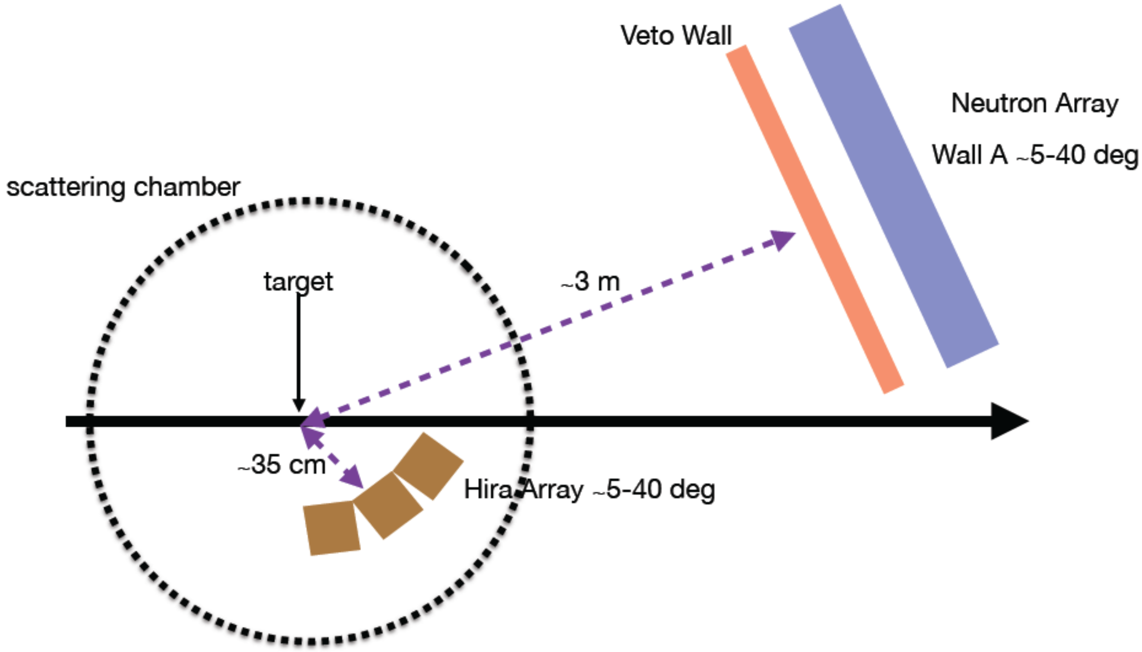

Figure 5: Experimental set up. The dashed circle represents the thin walled reaction chamber with the HiRA detectors placed inside.

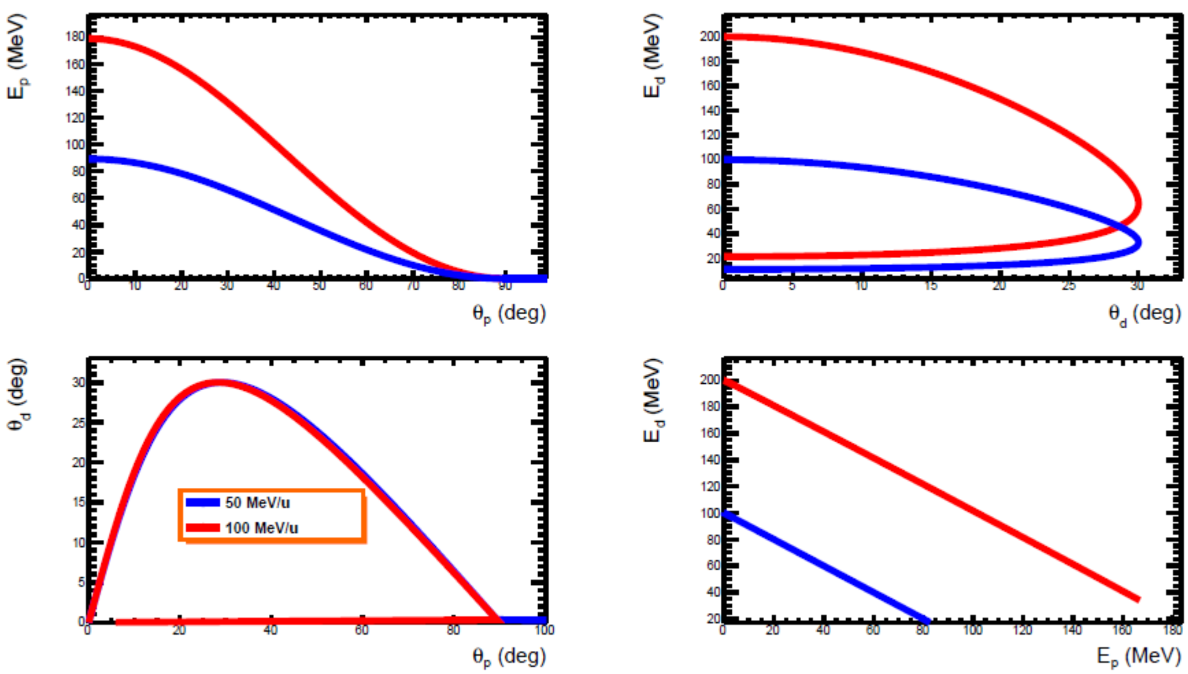

Figure 6: Kinematic diagrams for the p+d reactions at 50 and 100 MeV incident energies. The right most panel shows the emission angles of deuterons (detected by HiRA, y axis) and the angles of the recoiled proton detected by LANA and the CPV (x axis).

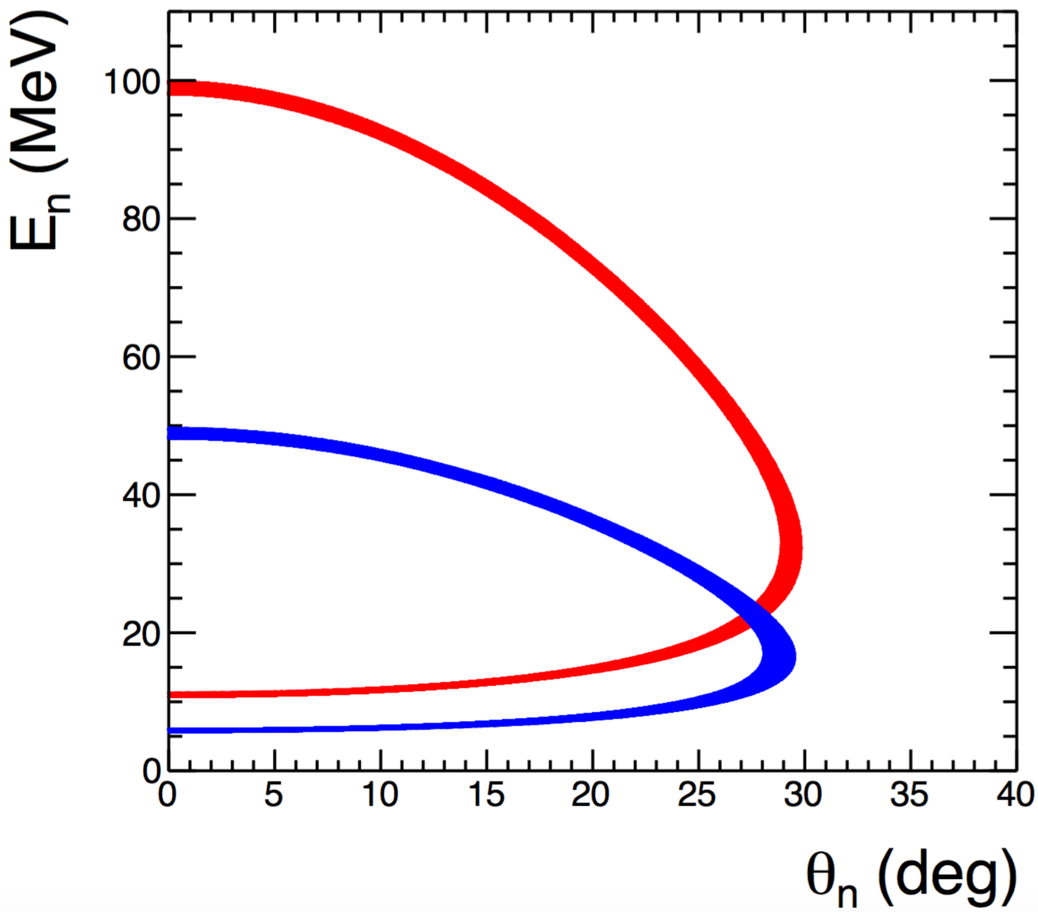

Figure 7: Kinematics of the neutron particles from the break-up of the d beam at 50 (blue lower curves) and 100 (upper red curve) MeV/u incident energies. Count rate estimate suggests that 16 hr of beam time should allow us to trace the kinematic line to 12 deg.

Primary beam	E/A (MeV/u)	Preparation time (hr)	Secondary beam	E/A (MeV/u)	Tuning time (hr)	Beam on target (hr)	Purpose
^{16}O	150	12	d	100	5	16	shake down
			d	100		16	test of CPV + LANA
			d	50	5	16	test of CPV + LANA
^{40}Ca	140	12	^{40}Ca	120	3	12	test of CPV + LANA with HIC
Total		24			13	60	**Total Request: 97 hours**

Table 1: Breakdown of beam request. Note that the primary beam development for the ^{40}Ca beam could be combined with the corresponding time in e14030.

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.

Expt #	date completed	PhD student	Year graduate	Responsible person	presentation	publication
1032	Jun-03			Famiano	numerous	Phys.Rev.Lett. 97, 052701 (2006)
				Tsang		Phys.Rev.Lett. 102, 122701 (2009).
				Tsang		Phys.Rev.C 86,015803 (2012)
1036	Jun-04	M. Mocko	2006	Mocko	numerous	Phys. Rev. C **74**, 054612 (2006)
				Mocko		Phys. Rev. C **76**, R067601 (2007)
				Mocko		Phys. Rev. C **76**, 041302 (2007)
				Tsang		Europhysics Letters, **79** (2007) 12001
				Mocko		Nucl.Phys.**A813**:293(2008)
				Mocko		Phys. Rev. C **78**,024612(2008)
				Winkelbauer		Phys. Rev. C **88**,044613(2013)
3031	May-05			Lukyanov		PRC 80, 014609 (2009).
2026	Oct-05	Wallace	2005	Wallace	numerous	NIMA 583, 302 (2007)
2023	Aug-05	Rogers	2009	Rogers	numerous	PRL106, 252503 (2011).
3045	Dec-06	M. Kilburn	2009	Henzl, Henzlova	numerous	PRC 85, 014606 (2011).
				Chajecki		Submitted to PRL
				Chajecki		Paper in preparation
5133	Dec-07	Jenny Lee	2010	Lee	numerous	PRL 102,062501 (2009)
				Lee		PR C83, 014606 (2011)
				Tsang		PR C88, 017604 (2013).
				Rogers		NIMA 707, 64 (2013)
06035	Dec-07	Sanetullaev	2010	Tsang	numerous	PLB 736, 137 (2014).
			2010	Rogers		arXiv:1309.2745Submitted to NIMA
07038	Jun-11	Winkelbauer	2015	Winkelbauer	numerous	Data being analyzed
05049	May-09	Showalter	2015	Showalter	numerous	Paper in preparation (Famiano's experiment)
09042	Nov-09	Coupland	2012	Coupland	numerous	Paper in preparation

		M. Youngs	2013	M. Youngs		Paper in preparation
10015	Dec-15			A. Rogers		Data being analyzed
09084	Nov-15	J. Manfredi		J. Lee		Data being analyzed
10001	Feb-13	K. Brown	2016	L. Sobotka	numerous	PRC **90**, 027304 (2014)
11001	May-13			R. Charity	numerous	PRC **92**, 034329 (2015)
						PRL **113**, 232501 (2014)
10011	Aug-13			A. Wuosmaa		Paper in preparation
12014				Chajecki		Experiment not scheduled
14002				Charity		Experiment not scheduled
14009				Wuosmaa		Experiment not scheduled
15109				Lynch		Experiment not scheduled
14030				Chajecki		Experiment not scheduled

Educational Impact of Proposed Experiment

If the experiment will be part of a thesis project, please include the total number of years the student has been in graduate school, what other experiments the student has participated in at the NSCL and elsewhere (explicitly identify the experiments done as part of thesis work), and what part the proposed measurement plays in the complete thesis project.

The project has actively engaged undergraduate students at the NSCL with its design. In addition John Bromell, an undergraduate student from Carleton College, was involved with Geant4 simulations of the experimental set up last summer when he was working under Lee Sobotka at Washington University. Construction of the veto wall can be a project for an incoming graduate student. Based on past experience, data from e14030 and e15190 will yield 3-4 theses. The neutron wall data taken with LANA+CPV can be the thesis for a new graduate student.