National Superconducting Cyclotron Laboratory
Proposal Form—PAC 33

TITLE: __ Density dependence of the symmetry energy with emitted neutrons and protons

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

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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**
Bickley, Abigail	NSCL	Lee, Jenny	NSCL (SGS)
Bonnet, Eric	LPC	Lemmon, Roy	Daresbury Laboratory, UK
Brege, Wyatt	GVSU (UG)	Lu, Fei	Peking University (SGS)
Caskey, Greg	Grand Valley State U	Mosby, Michelle	NSCL (GS)
Charity, Robert	Washington University	Novak, John	WMU (UG)
Chartier, Marielle	Liverpool University, UK	Pagano, Angelo	INFN, Sezione di Catania
Chbihi, Abdou	GANIL	Parker, Emma	WMU (UG)
Coupland, Dan	NSCL (GS)	Rogers, Andrew	NSCL (SGS)
Cruse, Krista	NSCL (GS)	Russotto, Paolo	INFN, Sezione di Catania
De Filippo, Erico	INFN, Sezione di Catania	Sanetullaev, Alisher	NSCL (GS)
Desouza, Romualdo	Indiana University	Shane , Rebecca	Washington U (GS)
Franklin, John	GANIL	Sobotka, Lee	Washington University
Giacherio, Brenna	WMU (GS)	Thompson, Paul	WMU (UG)
Henzl, Vladimir	NSCL (PD)	Verde, Giuseppe	INFN, Catania
Henzlova, Daniela	NSCL (PD)	Vilayurganapathy, Subba	WMU (GS)
Hudan, Sylvie	Indiana University	Wieleczko, Jean-Pierre	GANIL
Kadikara, Ravin	WMU (SGS)	Wu, P.	Liverpool University, UK
Kilburn, Micha	NSCL (SGS)	Youngs, Mike	NSCL (GS)
Lynch, Bill	NSCL		

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	124 Sn	120	0.1	15	72
Beam 2	124 Sn	50	0.1	3	48
Beam 3	16O	35	0.1	15	16
Beam 4	16O	25	0.1	3	16
Beam 5	112 Sn	120	0.1	15	48
Beam 6	112 Sn	50	0.1	3	48

ADDITITIONAL TIME REQUIREMENTS THAT REQUIRE USE OF THE CCF (e.g. modification of the A1900 standard configuration, development of optics, … Obtain estimates from the A1900 Device Contact.)

Additional CCF use time		
Total Hours:	54	248

NSCL PAC 33 – 1. Proposal Form

TOTAL TIME REQUEST (HOURS): __**302**__(Calculated as per item 5. of the Notes for PAC 33 in the Call for Proposals)

		SET UP TIME (before start of beam)	TAKE DOWN TIME
Access to:	Experimental Vault	__30____ days	__14_____ days
	Electronics Set-up Area	__30____ days	__14_____ days
	Data Acquisition Computer	__30____ days	__14_____ days

HOURS APPROVED: ________________ HOURS RESERVED: _____________________

WHEN WILL YOUR EXPERIMENT BE READY TO RUN? ____5/1/2009______

DATES EXCLUDED: ____8/15-8/30/2009________________________

EXPERIMENTAL LOCATION:

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

EXPERIMENTAL EQUIPMENT:

___	A1900	___	Beta Counting System	___	Beta-NMR Apparatus
___	92" Chamber	___	Sweeper Magnet	__X	Neutron Walls
___	Modular Neutron Array	___	Neutron Emission Ratio Observer		
___	High Resolution Array	__X	53" Chamber	___	CsI(Na) Scintillator Array

___ Segmented Ge Array [ ] classic [ ] mini [ ] beta [ ] delta [ ] plunger [ ] barrel [ ] other

___ S800 Spectrograph [ ] with [ ] without scattering chamber

___ Radio Frequency Fragment Separator X Other (give details): Miniball, LASSA

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

REACTION TARGETS AT EXPERIMENTAL STATION:

124Sn, 112Sn, CH_2

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 33 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.) [X] NONE

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

SUMMARY (no more than 200 words):

We propose to measure neutron and proton energy spectra, neutron and proton single and double ratios of the energy spectra and flows of neutrons and protons emitted from $^{124}Sn+^{124}Sn$ and $^{112}Sn+^{112}Sn$ collisions at E/A=50 and 120 MeV. Calculations indicate that measurements of pre-equilibrium neutron and proton emission directly probe the symmetry energy at the density corresponding to the time of emission. The double ratios measured in the proposed experiment will provide a much more stringent constraint on the density dependence of the symmetry energy. The neutron to proton ratios at E/A=120 MeV will test the proton and neutron effective masses assumed in transport calculations. Furthermore, this experiment will test the use of neutron to proton differential flow as an observable to explore the density dependence of the symmetry energy from low to high density. These measurements will be performed using the neutron walls in conjunction with the LASSA array, which will measure Hydrogen and Helium isotopes, the MSU Miniball, which will provide impact parameter selection, and the WMU fast plastic array, which will provide a start signal for the neutron time of flight.

Physics Justification

Information about the Equation of State (EOS) of asymmetric matter improves our understanding of neutron star properties such as stellar radii and moments of inertia, maximum masses [Lat01, Lat04, Ste05], crustal vibration frequencies [Wat06], and neutron star cooling rates [Yak04, Ste05], which are currently being investigated with ground-based and satellite observatories. Recent observations of neutron stars with the XMM-Newton X-ray telescope have been interpreted as requiring an unusually repulsive equation of state for neutron matter [Oze05], but these interpretations have not been confirmed [Rau08]. Laboratory measurements of isoscalar collective vibrations, collective flow and kaon production in energetic nucleus-nucleus collisions have constrained the equation of state for symmetric matter for densities ranging from saturation density to five times saturation density [Dan02, Fuc06, Gar05]. Extrapolation of these constraints to neutron stars also requires constraints on the density dependence of the symmetry energy. Some preliminary investigations of the density dependence of the symmetry energy have been performed [Tsa04, She04, Fam06], but the present constraints on the symmetry energy density dependence remain relatively weak [Bro00, Li08, Tsa08].

In the past decade, reaction probes such as isoscaling [Tsa01, She04], isospin diffusion [Tsa04], neutron to proton (n/p) ratios [Fam06], n/p flow [Li97], π^+/π^- ratios and π^+/π^- flow [Yon06], have been found to be sensitive to the density dependence of the symmetry energy. We propose to measure neutron to proton (n/p) ratios [Fam06, Li97, Li05] which have independent, strong and straight forward links to the symmetry energy. They can provide an important cross check of any constraints obtained using other probes, such as isospin diffusion or isoscaling.

To avoid sensitivity to the detection efficiencies for neutrons, we published comparisons [Fam06] of neutron to proton spectra from Exp. 01032 by employing a double ratio,

$$DR(n/p) = R_{n/p}(A)/R_{n/p}(B) = \frac{dM_n(A)/dE_{c.m.}}{dM_p(A)/dE_{c.m.}} \cdot \frac{dM_p(B)/dE_{c.m.}}{dM_n(B)/dE_{c.m.}}, \qquad (1)$$

constructed by measuring the energy spectra, $dM/dE_{C.M.}$, of neutrons and protons for two systems A and B that have different isospin asymmetries. The first measurements on the reactions A=^{124}Sn+^{124}Sn and B=^{112}Sn+^{112}Sn are shown as star symbols in the left panel of Fig. 1.

Calculations for DR(n/p) have been obtained using a sophisticated BUU model IBUU04 [Li06, Li08], with parameters adjusted [Che05] to reproduce the isospin diffusion data of ref. [Tsa04]. This latter comparison shown in the right panel of Figure 1 suggested that iso-EOS parameters (x=0 and x=-1) in the IBUU04 model were most consistent with the isospin diffusion data. Surprisingly, the IBUU04 calculations for DR(n/p) (solid and dashed lines, in left panel of Figure 1) lie far below the data near a no-sensitivity limit of $DR(n/p)=N_{124}Z_{112}/(N_{112}Z_{124})=1.2$ given by conservation laws. The discrepancy raises concerns about the constraints obtained via IBUU04 from reproducing the isospin diffusion data. As fluctuations are averaged out by the parallel calculations in BUU involving test particles, effect of cluster production cannot be included in the calculations. At incident energies of E/A=50 MeV where the present studies are conducted, cross sections for production of complex nuclei are significant and the influence of cluster production cannot be neglected [Zha07]. To investigate the influence of cluster production, we recently calculated both the actual double ratios and the coalescence invariant ratios using the Improved Quantum Molecular Dynamics (ImQMD) model [Zha07]. In the QMD approach, the N-body equations for nucleons are solved event by event. This enhances the importance of fluctuations and correlations in QMD and provides a mechanism to calculate the production of complex nuclei. The symmetry energy used in the ImQMD calculations is parameterized as sum of the kinetic and interaction terms.

$$E_{sym}\,(MeV) \approx 12.5(\rho/\rho_0)^{2/3} + 17.6(\rho/\rho_0)^{\gamma i} \qquad (2)$$

The comparisons of the ImQMD calculations to data are shown in Figure 2 for the measured double ratios DR(n/p) (left panel) and their coalescence invariant counterparts (right panel). The upper shaded regions in the left and right panels correspond to weaker density dependence of the interaction term in the symmetry energy with γ_i=0.5 and the lower shaded regions correspond to γ_i=2. Clearly, more accurate high energy data at E/A>40 MeV would enable significant constraints on the symmetry energy where complications from cluster production can be neglected. Better neutron and proton data allow simultaneous constraints on the density dependence of the symmetry energy with data from isospin diffusion, double n-p ratios DR(n/p), using the same transport theories [Tsa08].

The original design of the Exp. 01032 which produced the results published in Ref. {Fam06] should have provided sufficiently accurate data, but a design flaw in the CAEN V812 CFD's, used in the electronics for the neutron walls, rendered these modules unreliable. Two reports, written in 2004, document this problem [Tim04]. An analysis procedure was devised for Exp. 01032 to overcome this defect and resulted in the data shown in Figs. 1 and 2. This procedure, however, reduced the efficiencies of the walls at E_{cm}> 40 MeV by more than a factor of 10 and made the neutron efficiency difficult to determine. Since then, the V812 CFD's have been fixed, new CFD's have been designed, and a dedicated neutron area in S2 Vault has been reconfigured. With these developments, we are convinced that the normal efficiencies for the neutron walls will be achieved. This will be checked during Experiment 07018, Re-Commissioning of Large Area Neutron Array, scheduled to run April 29-May 3 2009. The expected uncertainties for the new data at E_{cm}>40 MeV will be reduced by at least a factor of three. The new experimental uncertainties will be better than those achieved in current theoretical calculations, allowing significant constraints on the symmetry energy. The new results will allow us to compare efficiency corrected neutron and proton spectra directly with predictions from transport theories in addition to comparing double ratios.

Measurements at high incident energy (>100A MeV) would allow sensitive tests of the isospin dependence of the nucleon effective masses. Fig. 3 shows the predictions for the ratio of the neutron and proton transverse momentum spectra for nucleons emitted with center-of-mass rapidities, y_{cm} of $|y_{cm}/y_{beam,cm}|<0.3$ in central ^{132}Sn+^{124}Sn collisions at 100 MeV/nucleon [Riz05]. Calculations for $m_p^*>m_n^*$ (squares) are compared to those for $m_p^*<m_n^*$ (circles) in each panel; the left and right panels show calculations assuming iso-soft and iso-stff density dependencies of the symmetry energy, respectively [Riz05]. We propose to measure the same quantity with the ^{124}Sn+^{124}Sn reactions at E/A=120 MeV. The asymmetry ([N-Z]/A) of the combined ^{124}Sn+^{124}Sn system (0.194) is somewhat smaller than that for ^{132}Sn+^{124}Sn (0.219), but this should still allow one to distinguish the case of $m_n^* > m_p^*$ from $m_n^* < m_p^*$. The high energy measurement would allow constraints on incident energy dependence of DR(n/p), which differs for the iso-stiff and iso-soft EOS's. By combining the measurements of E/A=50 and 120 MeV, we will be able to constrain both the momentum and density dependencies of the symmetry energy.

At beam energy much higher than E_{beam}>50 MeV, isospin diffusions used extensively at sub-saturation density to determine the density dependence of the symmetry energy will become unavailable as the collision time scale is too fast for isospin diffusion to occur. It is therefore important to find another observable that will extend to studies at higher density. Because the forces generated by the asymmetry term are of opposite sign for protons and neutrons, comparisons of neutron and proton transverse collective flow provide special sensitivity to the asymmetry term. This feature is illustrated for collisions at E/A=50 MeV in Figure 4 where predictions for mean proton and mean neutron transverse momenta in the reaction plane are compared as a function of the rapidity [Li00]. The upper and lower panels show predictions for EOS's with a more repulsive "asy-stiff" (upper panel) and a less repulsive "asy-soft" (lower panel) asymmetry term, respectively. The current set up will allow investigation of the neutron and proton differential flow simultaneously.

Goals of the proposed experiment

There are five principal goals for this experiments:

1. Obtain significantly more precise single and double n-p ratios for Sn+Sn collisions at E/A=50 MeV in order to place stringent constraints on the density dependence of the symmetry energy.
2. Perform a second set of single and double n-p ratio measurements at E/A= 120 MeV in order to place constraints on the isospin dependence of the nucleon effective masses.
3. Compare the measured energy dependence of the n-p double ratios in order to test the predicted sensitivity of this energy dependence to the density dependence of the symmetry energy.
4. Obtain efficiency corrected neutron spectra for testing the reliability of transport equation predictions for neutron, proton and other light particle spectra.
5. Obtain differential neutron and proton flows, which will be tested for its sensitivity to the density dependence of the symmetry energy from low to high density.

Experimental Details

The experimental equipment will consist of the MSU Miniball, the LASSA silicon strip detector array, and the neutron walls. A schematic layout of the experiment in Figure 5 shows the Miniball in the S2 scattering chamber along with the LASSA array. The multiplicities and transverse energies of charged particles detected by the Miniball, the LASSA and WMU fast plastic array will be used to determine the impact parameter. Neutron walls will be placed a distance of about 4-6 m from the target with an angular coverage in the lab of 15^0 to 60^0, providing excellent coverage for $70° \leq \theta_{cm} \leq 110°$. Comparable angular coverage for charged particles will be provided by six telescopes of the LASSA array. The start detector for the neutron wall will be the WMU thin segmented plastic scintillator array placed at forward angles. This array provides a timing signal with a resolution of less than 300 ps, that will also serve as the time reference for the neutron time of flight measurement. Exp. 01032 used a four-segment version of this device; Exp. 05049 [In-medium Cross Sections, Momentum and Density Dependence of Nuclear EOS] scheduled to run May 13 to May 24, will use a 16-segment version of this device. It would save a lot of manpower and time if this experiment is scheduled close behind Experiment 05049 so that both experiments use the same setup.

Based on our recent experiences running experiments with the MSU 4pi array, we anticipate we will be event rate limited at about 400 events/sec, corresponding to an incident beam intensity of about $3x10^8$ pps. Considering this rate and the statistical accuracy achieved in the previous experiment, we estimate that we will need 2 days of beam time on target to measure each beam-target combination. This beam time request includes taking data with shadow bars in front of the neutron detector to assess and control the neutron background due to scattering from the walls, floor etc. There are two different combinations needed: ^{124}Sn+^{124}Sn and ^{112}Sn+^{112}Sn and two different incident energies. This amounts to 8 days of data taking. In addition, we will need 24 hours of beam time to check the Miniball, LASSA and the neutron wall setup and to verify the trigger condition. This shake down is best done two weeks before the main experiment. For convenience, we add the shake down time to the request for ^{124}Sn beam. The debugging time can be substantially reduced by at least a factor of two and will not require a separate run to check the experimental setup if this experiment is scheduled to run before the setup of Exp. 05049 is taken apart. Thus it is preferable that the experiment is scheduled as soon as possible. To calibrate the LASSA telescopes with proton particles, we request 32 hours to scatter recoil protons from CH_2 target using two degraded ^{16}O beams of 15 and 30 MeV per nucleon. The calibration time may also be cut in half if the experiment can use the calibrations of experiment 05049. Degraded lighter primary beams such as O, Ni or Ca would be even more suitable for this purpose.

References:

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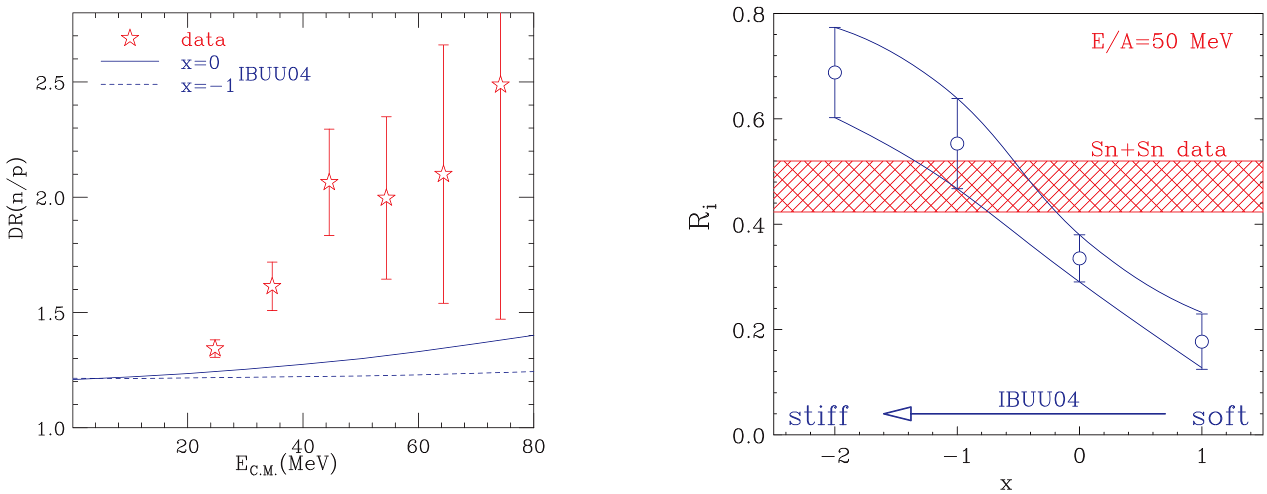

Fig.1: Left panel: The coalescence invariant neutron proton double ratios plotted as a function of kinetic energy of the nucleons. The solid (x=0) and dashed (x=-1) lines are the results of IBUU04 calculations from ref. [Li06]. The data (open star points) are taken from ref [Fam06]. Right panel: The isospin transport ratios plotted as a function of the stiffness parameter x used in IBUU04 [Li08] calculations (open circles). The isospin data shown in the shaded area are taken from ref. [Tsa04]

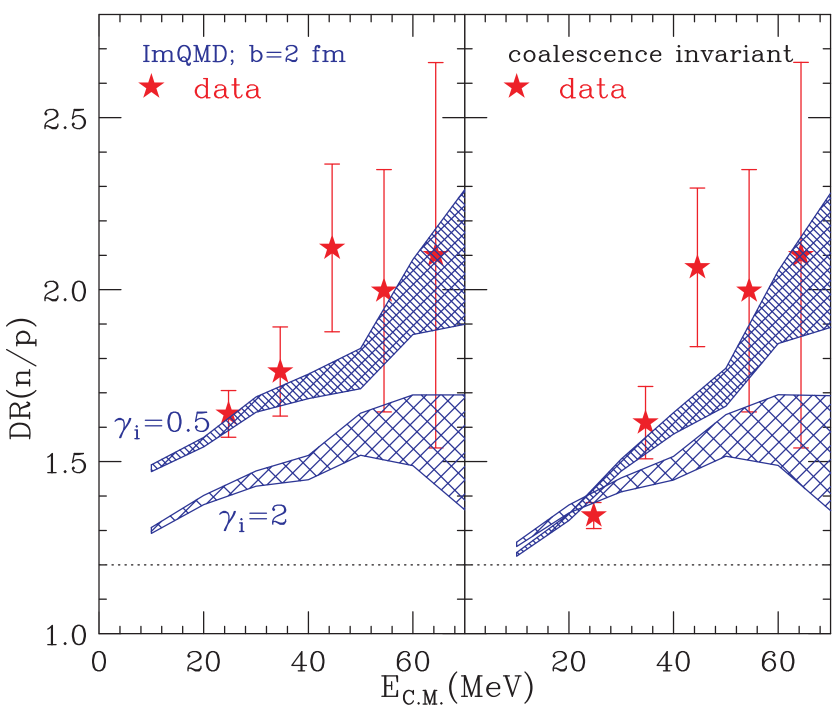

Fig.2: The free neutron-proton double-ratio (left panel), and the coalescence-invariant neutron-proton double-ratios (right panel) plotted as a function of kinetic energy of the nucleons. The data (star points) are taken from Ref [Fam06]. The shaded regions represent calculated results from the ImQMD simulations at b=2 fm with two different symmetry energy density dependent functions. The upper shaded regions use the iso-soft function (γ_i=0.5 of Eq. 2) and the lower shaded regions use the iso-stiff function (γ_i=2 of Eq. 2).

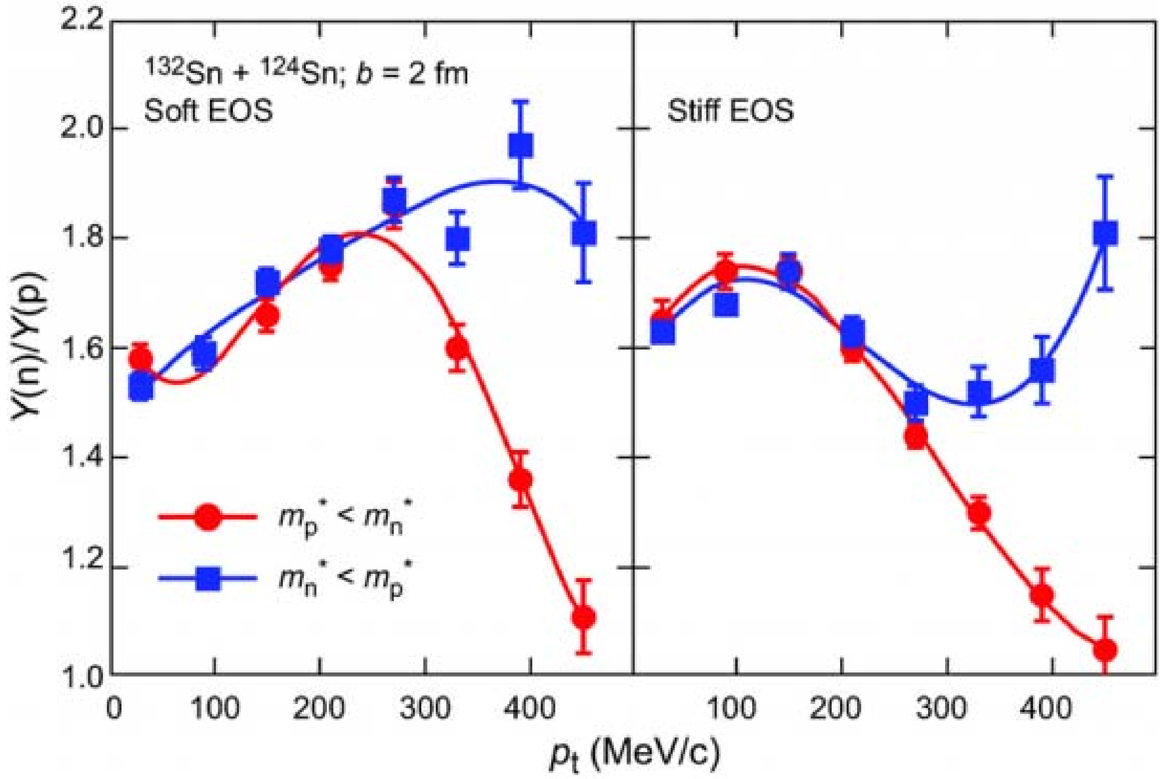

Figure 3: Ratio of neutron and proton spectra calculated for central ^{132}Sn+^{124}Sn collisions utilizing soft (left panel) and stiff (right panel) symmetry energy dependences. The squares and circles indicate calculations assuming $m_n^* < m_p^*$. and $m_n^* > m_p^*$, respectively. The lines are drawn to guide the eye. Adapted from [Riz05].

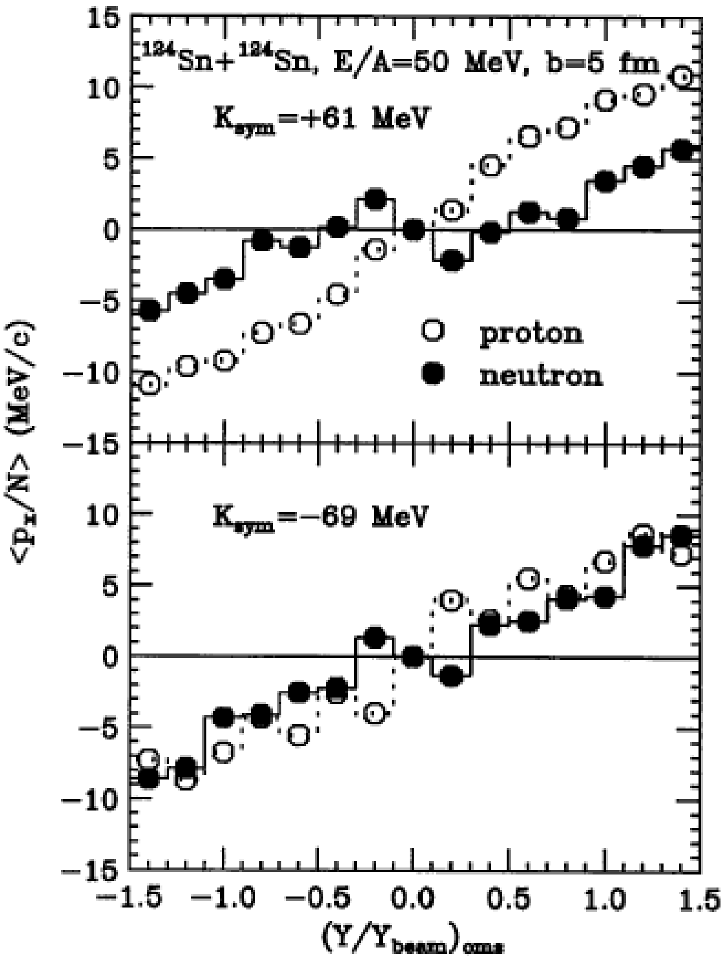

Fig 4. BUU calculations for the mean transverse momenta of protons and neutrons for symmetric ^{124}Sn collisions at E/A=50 MeV assuming an “stiff” asymmetry term (upper panel) and an “soft” symmetry term (low panel).

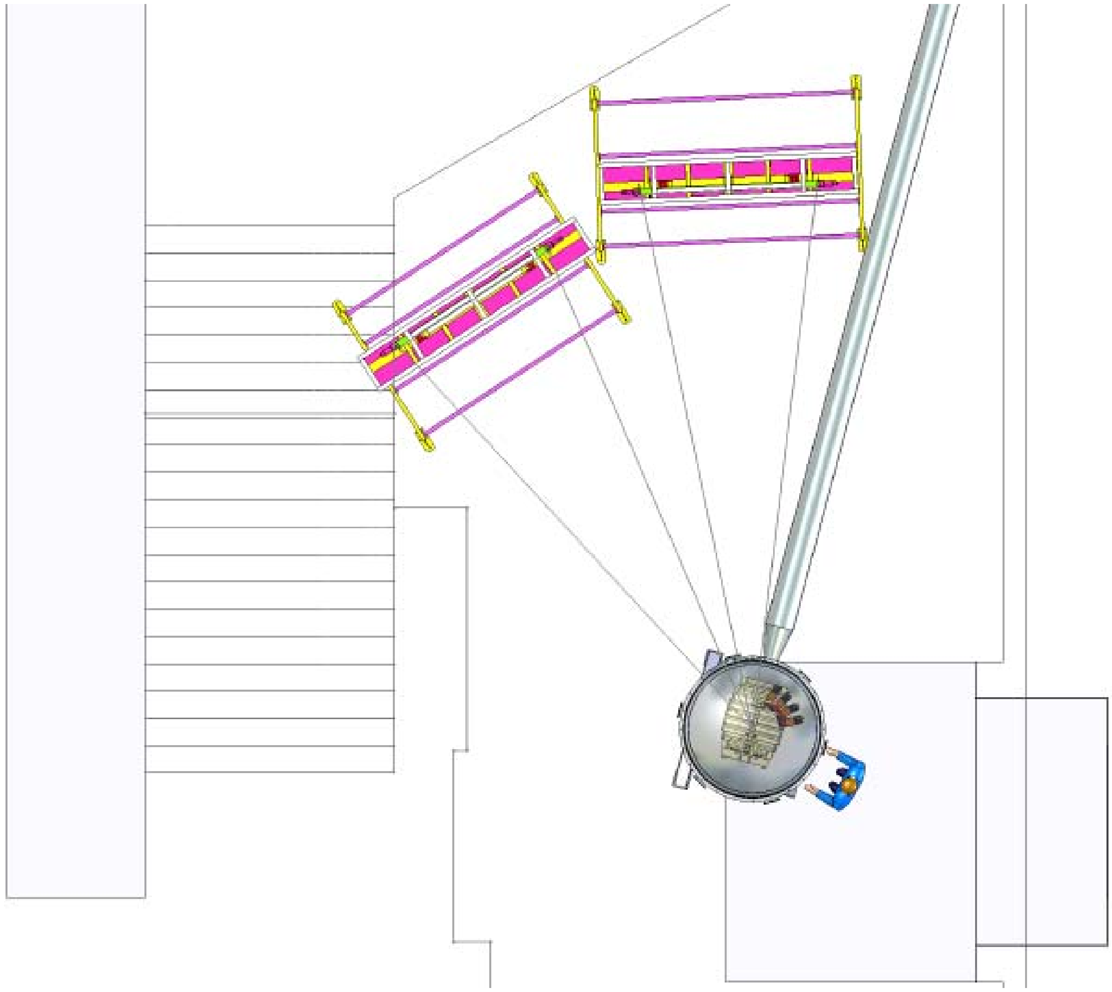

Figure 5: Overhead view of setup in the reconfigured S2 vault involving Miniball, LASSA (at forward angles) and two neutron walls.

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.

Status of experiments associated with Betty Tsang and Bill Lynch

Expt #	date completed	PhD student	Year graduate	Responsible person	presentation	publication
1032	Jun-03			M. Famiano	numerous	*Phys.Rev.Lett. 97, 052701 (2006)*
						PRL (in press) (2009) arXiv:0811.3107
1036	Jun-04	M. Mocko	2006	M. Mocko	numerous	*Phys. Rev. C **74**, 054612 (2006)*
						*Phys. Rev. C **76**, R067601 (2007)*
						*Phys. Rev. C **76**, 041302 (2007)*
						*Europhysics Letters, **79** (2007) 12001*
						*Nucl.Phys.**A813**:293(2008)*
						*Phys. Rev. C **78**,024612(2008)*
3031	May-05			S. Lukyanov		paper under preparation
2026	Oct-05	Wallace	2005	Wallace	numerous	*NIMA 583, 302 (2007)*
2023	Aug-05	Rogers	2009	Rogers	April APS meeting, 2008, NIX 2008	Data analysis near completion
2019	Oct-05			Charity	numerous	*Phys. Rev. C **76**, 064313 (2007)*
						*Phys. Rev. C **78**, 054307 (2008)*
5038	Jan-06			Bazin	INPC07	submitted to PRL
3045	Dec-06	M. Kilburn	2009	Henzl, Henzlova	April APS meeting, 2008	Data analysis finished, paper under preparation
5133	Dec-07	Jenny Lee	2010	Lee		Data being analyzed
						PRL 102,062501 (2009)
						arXiv:0809.4686 (submitted to PRC)
06035a	Dec-07	A. Sanetullaev	2010	A. Sanetullaev		Data being analyzed

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 Michael Youngs, a second year physics graduate student at MSU. He has been working as a research assistant at the NSCL since May 2006. He is involved with this proposal and the setup and execution of experiments 07018 and 05049. The proposed experiment will have the set up as these experiments. Thus Mr. Youngs should have no trouble carrying this project through.

This project would also actively engage undergraduates, graduate students and postdocs from NSCL, Western Michigan University, Washington University, and Grand Valley State University.

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.

^{60}Co, ^{137}Cs, ^{228}Th and ^{252}Cf sources are needed to calibrate the detectors.

Spectrograph Worksheet for S800 Spectrograph and Sweeper Magnet

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

1. Timing detectors

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

[ ] No
[ ] Yes

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

2. Tracking detectors

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

Are tracking detectors needed?

[ ] No
[ ] 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? ____ Hz

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

a) Which optics mode is needed?
   [ ] Dispersion matched [ ] focused [ ] Other _________________________
b) What are the maximum and minimum rigidities planned to be used for the analysis beam line?
   _____ Tm minimum, _____ Tm maximum
c) What are the maximum and minimum rigidity planned to be used for the spectrograph?
   _____ Tm minimum, _____ 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?
   _____ 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 33 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 33 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	^{112}Sn	________	
Energy	120	________	MeV/nucleon
Minimum intensity	3x10^{8}	________	particle-nanoampere

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

Beam-On-Target

Isotope	^{112}Sn	
Energy	120	MeV/nucleon
Rate at A1900 focal plane	________	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	________	% (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: 3 hrs

Total beam preparation time for this beam: 15 hrs

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

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

On-target time excluding device tuning: 72 hrs

Total on-target time for this beam: 72 hrs

Beam Request Worksheet

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

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	^{112}Sn	______	
Energy	120	______	MeV/nucleon
Minimum intensity	3×10^8	______	particle-nanoampere

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

Beam-On-Target

Isotope	^{112}Sn	
Energy	50	MeV/nucleon
Rate at A1900 focal plane	______	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	______	% (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: [3] hrs

Total beam preparation time for this beam: [**3**] **hrs**

Experimental device tuning time [see note (c) above]: [ ] hrs
S800 [ ] SeGA [ ] Sweeper [ ] Other [ ]
On-target time excluding device tuning: [48] hrs

Total on-target time for this beam: [**48**] **hrs**

Beam Request Worksheet

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

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	^{124}Sn	______	
Energy	120	______	MeV/nucleon
Minimum intensity	$3\text{x}10^8$	______	particle-nanoampere

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

Beam-On-Target

Isotope	^{124}Sn	
Energy	120	MeV/nucleon
Rate at A1900 focal plane	______	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	______	% (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: [3] hrs

Total beam preparation time for this beam: [15] hrs

Experimental device tuning time [see note (c) above]: [ ] hrs
S800 [ ] SeGA [ ] Sweeper [ ] Other [ ]
On-target time excluding device tuning: [48] hrs

Total on-target time for this beam: [48] hrs

Beam Request Worksheet

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

			Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	^{124}Sn	____	
Energy	120	____	MeV/nucleon
Minimum intensity	3×10^{8}	____	particle-nanoampere

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

Beam-On-Target

Isotope	^{124}Sn	
Energy	50	MeV/nucleon
Rate at A1900 focal plane	____	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	____	% (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: [3] hrs

Total beam preparation time for this beam: [3] hrs

Experimental device tuning time [see note (c) above]: [ ] hrs
S800 [ ] SeGA [ ] Sweeper [ ] Other [ ]
On-target time excluding device tuning: [48] hrs

Total on-target time for this beam: [48] hrs

Beam Request Worksheet

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

	Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	^{16}O	________	
Energy	150	________	MeV/nucleon
Minimum intensity	$3x10^8$	________	particle-nanoampere

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

Beam-On-Target

Isotope	^{16}O	
Energy	25	MeV/nucleon
Rate at A1900 focal plane	________	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	________	% (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: 3 hrs

Total beam preparation time for this beam: 15 hrs

Experimental device tuning time [see note (c) above]: ____ hrs
S800 [ ] SeGA [ ] Sweeper [ ] Other [ ]
On-target time excluding device tuning: 16 hrs

Total on-target time for this beam: 16 hrs

Beam Request Worksheet

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

				Beam Preparation Time	Beam-On-Target Time

Primary Beam (from beam list)

Isotope	^{16}O	______	
Energy	150	______	MeV/nucleon
Minimum intensity	$3x10^8$	______	particle-nanoampere

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

Beam-On-Target

Isotope	^{16}O	
Energy	35	MeV/nucleon
Rate at A1900 focal plane	______	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	______	% (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: [3] hrs

Total beam preparation time for this beam: [3] hrs

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

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

On-target time excluding device tuning: [16] hrs

Total on-target time for this beam: [16] hrs