NSCL PAC 31 – 3. Proposal Data Form

TITLE: _Precision measurements of isospin diffusion_______

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

SPOKESPERSON: William Lynch

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BACKUP SPOKESPERSON: Dan Coupland

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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**
Kilburn, Micha	NSCL (GS)	Henzl, Vladimir	NSCL (PD)
Henzlova, Daniela	NSCL (PD)	Lee, Jenny	NSCL (GS)
Rogers, Andy	NSCL (GS)	Sanetullaev, Alisher	NSCL (GS)
Famiano, Michael	Western Michigan U	Desouza, Romualdo	Indiana
Tsang, Betty	NSCL	Sobotka, Lee	Washington U
Charity, Robert	Washington U	Hudan, Sylvie	Indiana
Bickley, Abigail	NSCL	Bazin, Daniel	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	1.5	18	92
Beam 2	118 Sn	120	1.5	18	48
Beam 3	112 Sn	120	1	18	48
Beam 4	78 Kr	150	25	18	16

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:	72	204

TOTAL TIME REQUEST (HOURS): ____276

NSCL PAC 31 – 3. Proposal Data Form

(Calculated as per item 4. of the Notes for PAC 31 in the Call for Proposals)

HOURS APPROVED: ________________ HOURS RESERVED: ____________________

		SET UP TIME (before start of beam)	TAKE DOWN TIME
Access to:	Experimental Vault	30 days	7 days
	Electronics Set-up Area	30 days	7 days
	Data Acquisition Computer	10 days	7 days

WHEN WILL YOUR EXPERIMENT BE READY TO RUN? 12 / 31 / 2007

DATES EXCLUDED:

EXPERIMENTAL LOCATION:

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

EXPERIMENTAL EQUIPMENT:

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

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

DETAIL ANY REQUIREMENTS THAT ARE OUTSIDE THE CURRENT NSCL OPERATING ENVELOPE, OR CHECK NONE (Examples: vault reconfiguration, new primary beam, primary beam intensities above what is presently offered, special optics, operation at unusually high or low rigidities): [x] NONE

TARGETS:
124Sn, 118Sn, 112Sn, 197Au

LIST ALL RESOURCES THAT YOU REQUEST THE NSCL TO PROVIDE FOR YOUR EXPERIMENT BEYOND THE STANDARD RESOURCES OUTLINED IN ITEM 11. OF THE NOTES FOR PAC 31 IN THE CALL FOR PROPOSALS.

LIST ANY INTERRUPTIONS REQUIRED IN RUNNING YOUR EXPERIMENT: (Examples of why an experiment might need an interruption: to change the experimental configuration; to complete the design of an experimental component based on an initial measurement.)

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

SUMMARY (no more than 200 words):

We propose to measure the isotopic distribution of projectile residues from the collisions of Sn isotopes, which differ in their isospin asymmetry. Such measurements potentially offer a uniquely direct comparison to transport theory because they suffer no ambiguities concerning the particle production mechanism or the reaction timescale. These measurements will be performed using the S800 spectrograph in coincidence with a 4π charged particle detection array. This will provide impact parameter selection and measurements of the diffusion rate from the yields of fragments with $3 \leq Z \leq 8$ that can be compared and cross calibrated with the residue fragment data.

Description of Experiment

Physics Justification:

The nuclear Equation of State (EOS) describes the relationships between the energy, pressure, temperature, density and isospin asymmetry $\delta=(\rho_n-\rho_p)/\rho$ for a nuclear system [Dan02]. The symmetry energy term, which governs the asymmetry dependence of the EOS, also governs many properties of neutron stars, such as stellar radii and moments of inertia, maximum masses [Lat01, Lat04, Ste05], crustal vibration frequencies [Wat06], and neutron star cooling rates [Yak04, Ste05]. Measurements have constrained the equation of state for symmetric matter for densities ranging from saturation density to five times saturation density [Dan02, Fuc06, Gar05]. Until recently, constraints on the density dependence of the symmetry energy have been rather weak [Bro00].

In this proposal we outline a set of measurements of isospin diffusion [Tsa04] that can provide significant constraints on the density dependence of the symmetry energy at sub-saturation densities, $\rho/\rho_0 \approx 0.5$-1 [Shi03, Tsa04, Che05] Such studies involve comparing A+B collisions of a neutron-rich (A) nucleus and a proton-rich (B) nucleus to symmetric collisions involving two neutron-rich nuclei (A+A) and two proton-rich (B+B) nuclei under the same experimental conditions [Tsa04]. When the collision involves projectile and target nuclei (A+B or B+A) with different isospin asymmetries $\delta = (N-Z)/A$, the symmetry energy enhances the diffusion rate that drives the system towards isospin equilibrium so that the difference between neutron and proton densities is minimized. Effects other than diffusion such as the preequilibrium emission from a neutron-rich (A) projectile should be approximately the same for asymmetric A+B collisions as for symmetric A+A collisions. Similarly, non diffusion effects from a proton-rich (B) projectile in B+A collisions and B+B collisions should be the same. Thus the comparison of asymmetric A+B collisions to symmetric A+A and B+B collisions allows one to isolate isospin diffusion and consequently probe the symmetry energy.

The most important quantity to determine is the asymmetry of the projectile-like residue immediately after the collision and prior to secondary decay because this is the quantity that is calculated in transport theory [Shi03, Tsa04, Che05]. To do this, one can measure an observable X that is linearly dependent on the residue asymmetry, i.e. $X = a\cdot\delta+b$, and construct the corresponding isospin transport ratio $R_i(X)$

$$R_i(X) = 2\frac{X-(X_{A+A}+X_{B+B})/2}{X_{A+A}-X_{B+B}} \qquad (1)$$

Then, trivial substitution provides that $R_i(X)=R_i(\delta)$ and one dispenses with most of the uncertainty associated with determining δ from measurements of X. This technique is very precise but could be questioned if one does not experimentally demonstrate that the observable X varies linearly with δ. Alternatively, one can simply calculate $R_i(X)$ from $R_i(\delta)$ with a residue decay theory, for each of the values of δ predicted by transport theory for the various density dependent symmetry terms [Tsa04]. This suffers due to the model dependencies and limited statistical precision of residue decay calculations [Tsa04].

In our published data, we used the isoscaling parameter ($X=\alpha$) from collisions involving the asymmetric ^{124}Sn+^{112}Sn (A+B) and ^{112}Sn+^{124}Sn (B+A) systems and the two symmetric systems ^{124}Sn+^{124}Sn (A+A) and ^{112}Sn+^{112}Sn (B+B) [Tsa04]. Isoscaling parameters α and β are typically obtained from the ratios of isotopic yields from two reactions that differ essentially in their isospin compositions:

$$R_{21}(N,Z)=Y_2(N,Z)/Y_1(N,Z)= C\exp(\alpha N+\beta Z). \qquad (2)$$

Here, $Y_i(N,Z)$ is the yield of the measured fragments with neutron number N and proton number Z emitted in reaction i (i=1,2), α is the neutron isoscaling factor, β is the proton isoscaling factor and C is the normalization constant obtained by fitting the isotope yield ratios to Eq. (2). In the experiments, yields from the ^{124}Sn+^{112}Sn (A+B), ^{112}Sn+^{124}Sn (B+A) ^{124}Sn+^{124}Sn (A+A) and ^{112}Sn+^{112}Sn (B+B) were each divided by the yields from the $^{112}Sn+^{112}Sn$ (B+B) reaction to obtain the isoscaling parameter for the reaction 2 in the numerator of Eq. (2)

Relations between α, β, and α-β and δ have been obtained for evaporative and multifragment decays of an excited projectile-like fragment and both theories predict a linear dependence of α, β, and α-β on the residue asymmetry δ [Bot02,Tsa01]:

$$\alpha = \Delta\mu_n / T = 2C_{sym}(\Delta\delta)(1-\overline{\delta})/T,$$
$$\beta = \Delta\mu_p / T = -2C_{sym}(\Delta\delta)(1+\overline{\delta})/T,$$
$$and$$
$$\alpha - \beta = (\Delta\mu_n - \Delta\mu_p)/T = 4C_{sym}(\Delta\delta)/T, \quad (3)$$

where $\Delta\delta=\delta_2-\delta_1$ and $\overline{\delta}=(\delta_2+\delta_1)/2$ are the differences and the mean of the asymmetries of the emitting source, and C_{sym} is the coefficient of the symmetry energy term in the nuclear Gibbs free energy.

Such predictions have not quieted skeptics who question whether α, β, and α-β depend linearly on the residue asymmetry δ. The linear dependence of the isoscaling parameters on δ, has also been experimentally demonstrated, but only for central collisions. In the upper panel of Figure 1, we compare the values for α, β, and α-β obtained at mid-rapidities for central $^{112}Sn+^{112}Sn$ (δ = 0.107), $^{112}Sn+^{124}Sn$ (δ = 0.153) and $^{124}Sn+^{124}Sn$ (δ = 0.194) collisions as a function of the total asymmetry using the data of ref. [Liu04]. Figure 1 clearly establishes the linear dependence of the isoscaling parameters on δ for central collisions, independent of theory. **It is important to establish whether α, β, and α-β depend linearly on δ for peripheral collisions because that would settle this question regarding the link between the measured values $R_i(X)$ and the values $R_i(\delta)$ calculated by transport theory, making the theoretical predictions less model dependent. This is one of the goals of the present proposal.**

The shaded boxes in Figure 2 show the published isospin transport ratio analyses using X=α, which yielded values of about 0.5±0.15 at y/y_{beam} = 0.7-1.0 (from $^{124}Sn+^{112}Sn$ collisions) and -0.5±0.18 at y/y_{beam}=0-0.3 (from $^{112}Sn+^{124}Sn$ collisions) at an impact parameter gate of $0.8 \le b/b_{max} \le 1$ (b≈6 fm) [Tsa04]. The quantity α-β can also be related to the ratios of yields of mirror nuclei Y(N,Z) and Y(Z,N) (where |N-Z|=1), providing additional diffusion observables. From these ratios, one obtains:

$$X_A = \ln(Y_2(N,Z)/Y_1(Z,N)) = \alpha-\beta+\ln(C) \quad (7)$$

where A=N+Z and C is a constant. Figure 1 shows that X_7 and X_{11} also depend linearly on δ. The rapidity dependence of the isospin transport ratio $R_7 \equiv R_i(X_7)$ obtained from the $Y(^7Li)/Y(^7B)$ mirror nucleus ratio in our previous experiment is shown by the data points in Figure 2 [Liu06]; R_7 is nearly flat near the projectile and the target rapidity regions before dropping to zero around mid-rapidity. This comparison indicates that these fragments observables are not very sensitive to details of the fragment rapidity gate. Other analyses also indicate that the dependence on the transverse momenta of the detected fragments is small as well.

The scientific potential of the isospin transport ratio measurements to place constraints on the density dependence of the symmetry energy is illustrated by Figure 3. In this figure, the circles show corresponding values for R_i [Tsa04] calculated with the Bolzmann-Euhling-Uhlenbeck (BUU) equation at an impact parameter of b≈6 fm for symmetry energy terms with different density dependencies. These calculations are arranged from left to right in the order of increasing stiffness of the density dependence; the intersection of theoretical and experimental values provides some indication of the range of density dependencies for which the data and calculations are consistent. The figure also summarizes model calculations [Che05, Li06, Ste05], with the same symmetry energies, of the radii of 1.4 solar mass neutron stars (upper axis) and of the difference between neutron and proton radii for ^{208}Pb (lower axis). While the constraints shown in Figure 3 are preliminary, the figure illustrates relationships that exist between these quantities, which all depend sensitively on the symmetry energy.

The proposed experiment will control the important experimental factors that limit the accuracy of the accuracy of the measured transport ratio R_i and consequently the accuracy of the constraints themselves. Other theoretical uncertainties concerning the isospin dependencies of the nucleon effective masses and medium modified nucleon-nucleon cross sections will be constrained by other measurements, such as approved experiment 05049.

Goals of the proposed experiment:

The primary goal is to address the issues that limit the accuracy of the isospin transport ratios. These are:

1) Establish whether the isoscaling parameters depend linearly on the asymmetry δ for peripheral collisions, independent of theory. **This will be done by adding a measurement of ^{118}Sn+^{118}Sn collisions, which is midway between the asymmetries of ^{124}Sn and ^{112}Sn and will provide a data point corresponding to isospin equilibrium for the asymmetric ^{124}Sn + ^{112}Sn and ^{112}Sn + ^{124}Sn systems.**

2) Improve the accuracy of the impact parameter determination. The impact parameter was determined for the last experiment from the charge particle multiplicity and calibrated by a direct measurement of the cross section corresponding to that multiplicity. Figure 4 shows the rapidity dependence of R_7 for $y/y_{beam} > 0.5$ with three impact parameter gates: the peripheral gate ($b/b_{max} > 0.8$) discussed earlier, a mid-impact parameter gate ($0.4 < b/b_{max} < 0.6$) and a central collision gate ($0 < b/b_{max} < 0.2$). To reduce the error bars, we have taken advantage of the approximate symmetry of R_7, i.e. $R_7(y/y_{beam}) = -R_7(0.5- y/y_{beam})$ to combine data from ^{124}Sn+^{112}Sn collisions with data from ^{112}Sn+^{124}Sn collisions. The shape of R_7 changes significantly with impact parameter. For $b/b_{max} > 0.8$ where our previous results were published, R_7 makes a rapid transition through zero near $y/y_{beam} = 0.5$ and then remains roughly constant at $y/y_{beam} > 0.7$. For mid-central collisions, $0.4 < b/b_{max} < 0.6$, R_7 changes linearly with rapidity. For central collisions, $0 < b/b_{max} < 0.2$, R_7 remains close to 0 for $0.5 < y/y_{beam} < 0.8$ and then increases rapidly near projectile rapidity. This strong impact parameter dependence makes it clear that increased accuracy in the constraints from isospin diffusion will follow from a better understanding of our impact parameter determination. **We will achieve a better understanding of our impact parameter selection in the proposed experiment. This will be achieved by combining charge particle multiplicity and transverse energy selections using the Miniball and LASSA arrays with residue fragment measurements using the S800 Spectrograph. The observables will be combined together and both will be compared to molecular dynamics calculations to understand how to maximize the precision of the impact parameter selection. Absolute cross sections will be used to provide an absolute calibration of the impact parameter scale.**

3) Determine the isospin transport ratios $R_i(X)$ for fragments that come unambiguously from residue decay. Present theoretical calculations assume that the projectile-like residue emits the fragments whose yields are involved in the computation of $R_i(X)$ after the two residue separates. While this is certainly true for many of the fragments included in the previous isospin diffusion measurement, it may not be true for all. Fragments that are emitted before the residues separate will reflect the asymmetry δ at an earlier stage of the reaction when the diffusion is less complete. **This is the most important question we will resolve with the proposed experiment. It will be resolved by measuring the isospin transport ratios $R_i(X)$ for fragments from residue decay using the S800 Spectrograph.**

4) Investigating the feasibility of experiments with higher precision that use rare isotope beams. If the proposed isospin diffusion measurements are successful, the larger cross sections of residues will permit us to try to improve the sensitivity of such studies by maximizing the asymmetry difference between projectile and target by using lower intensity rare isotope beams, which increases the number of neutrons diffused between projectile and target. Future experiments with ^{108}Sn beams may be feasible with current intensities, which would increase the possible asymmetry difference over that we would explore with ^{112}Sn beams on ^{124}Sn. It is also important to address whether surface effects are properly treated in the BUU calculations. Experiments with ^{68}Ni and ^{56}Ni or ^{37} Ca and ^{48}Ca beams are also feasible at the CCF at

MSU. The current proposal is an important first step towards the exploration of isospin diffusion with rare isotope beams.

Expermental Details:

The experimental equipment will consist of the MSU Miniball, the LASSA silicon strip detector array, and the S800 spectrograph. A schematic layout of the experiment in Figure 5 shows selected rings of the Miniball in the S800 scattering chamber along with the LASSA array. In this figure, only one of the Miniball rings at laboratory angles of less than 90° are shown in order to reveal the location of the target and the LASSA array.

The multiplicities and transverse energies of charged particles detected by the Miniball and the LASSA will be used to determine the impact parameter. These two devices were used to measure the previous isospin diffusion shown in Figures 1-4 [Liu06]. In this experiment, the LASSA will be centered at 0 degrees, with the center telescope removed to allow the passage of the beam. Complementary information about the impact parameter will be obtained from the projectile residue decay fragments with $25<Z<40$ detected in the S800 spectrograph.

Isospin transport ratios for fragments with $3\leq Z\leq 8$ will be measured with LASSA to cross check them with the isospin transport ratios from residue decay fragments measured with the S800 spectrograph. We have simulated the response of the spectrograph to these fragments. Most of the fragments will be emitted at angles of less than 2.5^0, well inside the acceptance of the spectrograph. With momentum and focal aperture settings chosen to avoid beam charge states, it is possible to obtain the residue fragments data with 5-6 magnetic settings.

Based on our recent experiences running experiments with the S800 spectrograph and 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 less than $3x10^8$s. Considering this rate and the statistical accuracy achieved in the previous experiment, we estimate that we will need 1 day of beam time on target to measure each beam-target combination. There are 6 different combinations needed: ^{124}Sn+^{124}Sn, ^{124}Sn+^{112}Sn, ^{112}Sn+^{124}Sn, ^{112}Sn+^{112}Sn, ^{118}Sn+^{118}Sn and ^{118}Sn+^{112}Sn. In addition, we will need 40 hours of beam time to set up the Miniball, LASSA and S800 and to check the trigger condition. The debugging is best done with the stable ^{124}Sn or ^{112}Sn beams. For convenience, we add the debugging time to the request for ^{124}Sn beam.

We request that 16h of this requested debugging time to be used for a test of the Miniball during a test run that should occur at least 3 weeks prior to the experiment. This can be done with any beam with $Z\geq 20$. Finally, we request 16 hours to scatter fragmentation protons, alphas, ^{7}Li's, ^{7}Be's and other fragments with BRHO=1.325 TM from an Au target to calibrate the LASSA array. LISE does not accurately calculate the production of light ions by fragmentation, but from our past experience in experiment 02023, we know that sufficient intensity was provided for this purpose by fragmenting a ^{78}Kr beam at E/A=140 MeV. Lighter beams such as O, Ni or Ca will provide even higher intensities. The primary Sn beams will not be of sufficient intensity for this purpose.

References:

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[Yak04] D.G. Yakovlev and C.J. Pethick, Annu. Rev. Astron. Astrophys. 42, 169 (2004).

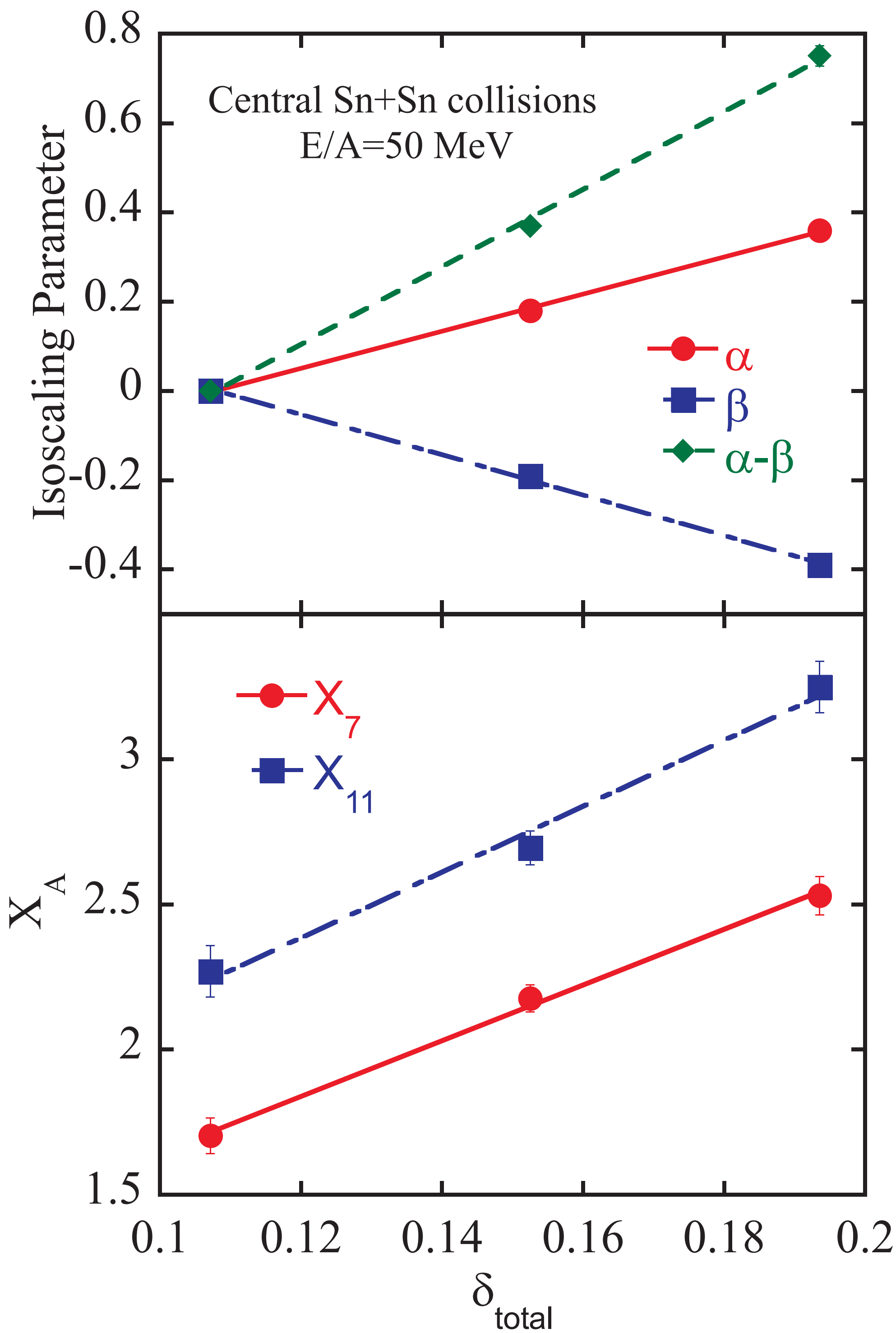

Figure 1: Upper panel: The solid circles, solid squares and open diamonds show the experimental data for α, β and α-β, respectively, that have been measured for central Sn+Sn collisions. The x axis corresponds to the isospin asymmetry of the combined system. Lower panel: The solid circles, and solid squares show the experimental data for X_7 and X_{11}, respectively, that have been measured for central Sn+Sn collisions.

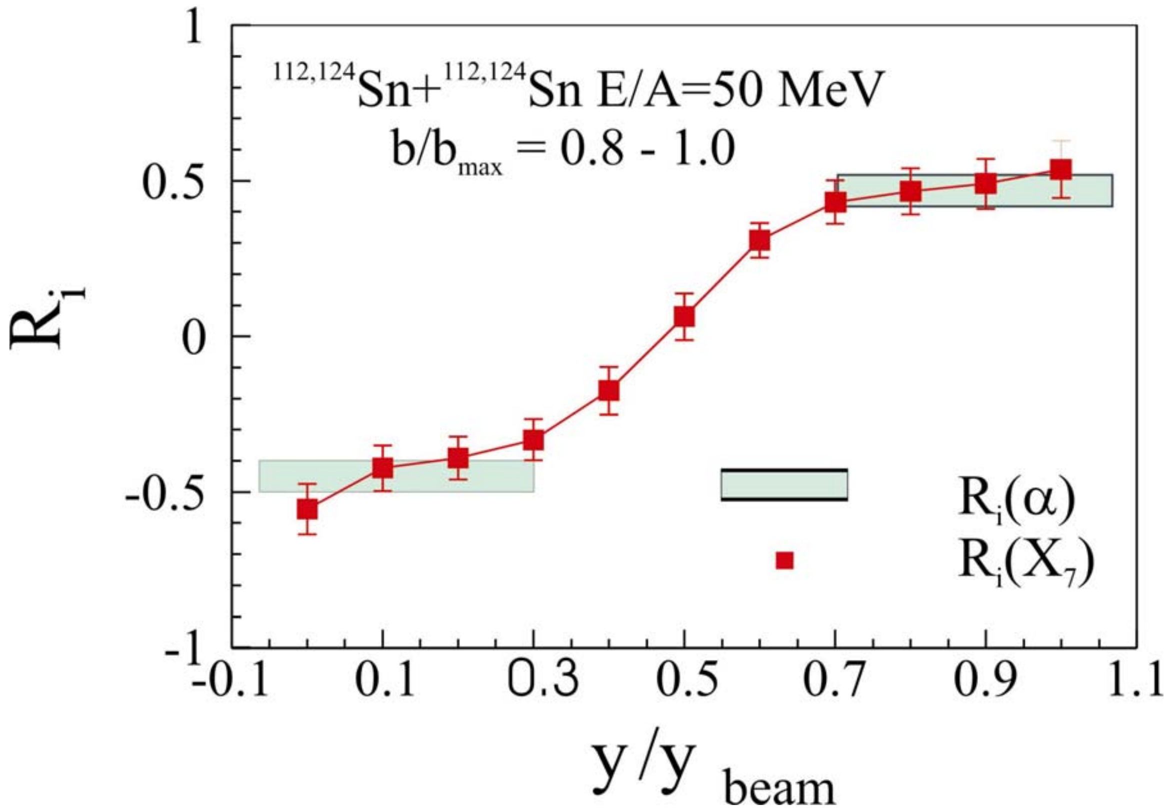

Figure 2: The solid rectangles at $0 < y/y_{beam} < 0.3$ and $0.7 < y/y_{beam} < 1.0$ show the values of $R_i(\alpha)$ measured for the $^{124}Sn+^{112}Sn$ and $^{112}Sn+^{124}Sn$ systems, respectively [Tsa04]. The data points show the values of $R_i(X_7)$ measured for A=7 mirror nuclei in peripheral $^{124}Sn+^{112}Sn$ collisions as a function of rapidity.

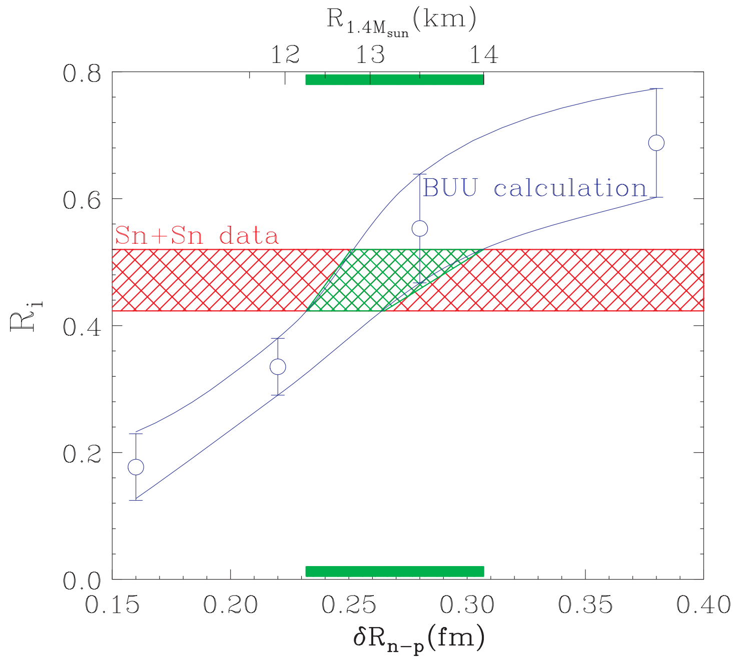

Figure 3: Comparison of measured [Tsa04] (red crosshatched region) and calculated [Li06] (solid points) values for the isospin transport ratio R_i. The theoretical error bars represent the statistical uncertainties of the theoretical simulations. The top and bottom scale summarize model calculations [Li06] for radii of 1.4 solar mass neutron stars (top scale) and for the difference between neutron and proton radii of ^{208}Pb (bottom scale) for those symmetry energy functions that were used in calculating the isospin transport ratio.

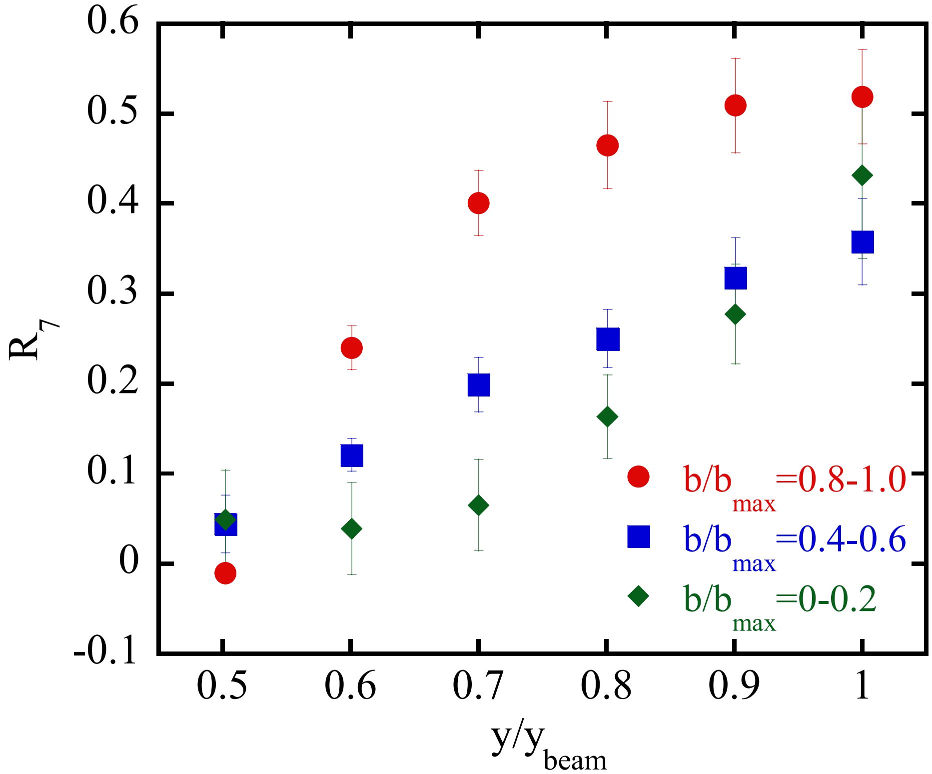

Figure 4: The open diamonds, solid squares and solid circles show the rapidity dependencies of R_7 for central, mid-central and mid-peripheral collisions, respectively.

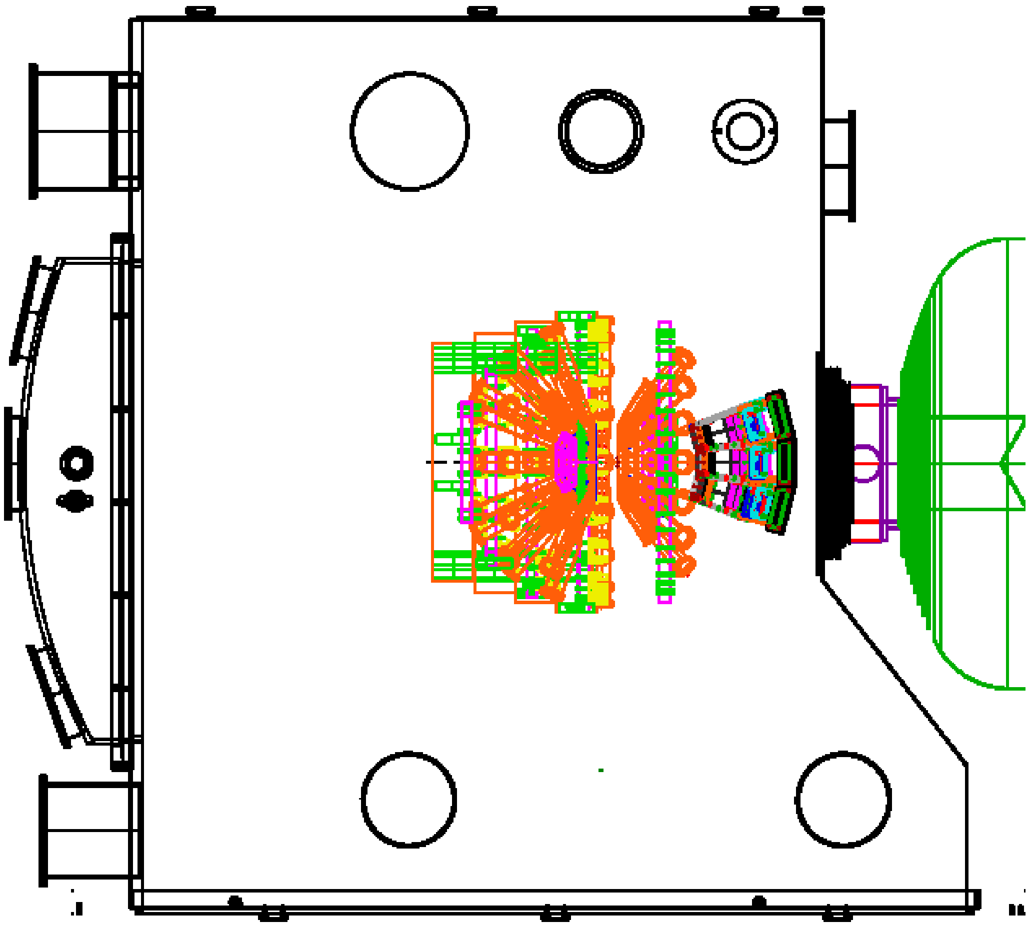

Figure 5: Overhead view of setup involving Miniball, and LASSA (at forward angles) with both inside the S800 scattering chamber.

Status of Previous Experiments

Results from, or status of analysis of, previous experiments at the CCF listed by experiment number. Please indicate publications, presentations, Ph.D.s awarded, Master's degrees awarded, undergraduate theses completed.

Experiment 01032 was finished in 2003 and the result was published in Physical Review Letters. [M.A.Famiano et al., Phys.Rev.Lett. 97, 052701 (2006)]

The HiRA+4pi experiment, 03045 was finished in December last year. It is the thesis experiment for Micha Kilburn and the data are being analyzed by Micha as well as our two postdocs Henzl and Henzlova.

Experiment 03031 was run in May, 2005. The data analysis is finished. A paper is under preparation. The last campaign involving HiRA for Experiment 02018, 02019, 02023 and 05038 were completed at the middle of January, 2006. Calibrations of the HiRA detectors for expt 05038 and 02026 have been finished. The data analysis for 02023, the thesis experiment of Andy Rogers, has started. The data of experiment 02019 is being analyzed by the Washington University group.

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 Dan Coupland, a first year physics graduate student at MSU. He has been working as a research assistant at NSCL since Fall, last year. He is fully involved with this proposal and should have no trouble carry this project through.

This project would also actively engage undergraduate, graduate students and postdocs from NSCL and Western Michigan 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 review will be required prior to scheduling and you will need to designate a Safety Representative for your experiment.

SAFETY CONTACT FOR THIS PROPOSAL: Betty Tsang

HAZARD ASSESSMENTS (CHECK ALL ITEMS THAT MAY APPLY TO YOUR EXPERIMENT):

____x_____ Radioactive sources required for checks or calibrations.
__________ Transport or send radioactive materials to or from the NSCL.
__________ Transport or send— to or from the NSCL—chemicals or materials that may be considered hazardous or toxic.
__________ Generate or dispose of chemicals or materials that may be considered hazardous or toxic.
__________ Mixed Waste (RCRA) will be generated and/or will need disposal.
__________ Flammable compressed gases needed.
__________ High-Voltage equipment (Non-standard equipment with > 30 Volts).
__________ User-supplied pressure or vacuum vessels, gas detectors.
__________ Non-ionizing radiation sources (microwave, class III or IV lasers, etc.).
__________ Biohazardous materials.

PLEASE PROVIDE BRIEF DETAIL ABOUT EACH CHECKED ITEM.

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

Spectrograph Worksheet for S800 Spectrograph and Sweeper Magnet

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

1. Timing detectors

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

[X] No
[ ] Yes

i. What is the desired thickness? [X] 125 µm [ ] 1 mm [ ] other _____
ii. What maximum rate is expected on this scintillator? _10^6__ Hz

2. Tracking detectors

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

Are tracking detectors needed?

[X] No
[ ] Yes

3. Focal-plane rates

a) What detectors are planned to be used? Extended focal plane.
b) What is the maximum rate expected in the focal-plane detection system? _10^6_ Hz

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

a) Which optics mode is needed?
[ ] Dispersion matched [X] focused [ ] Other ___________________________
b) What are the maximum and minimum rigidities planned to be used for the analysis beam line?
_1.3__ Tm minimum, __2.6_ Tm maximum
c) What are the maximum and minimum rigidity planned to be used for the spectrograph?
_1.9_ Tm minimum, _2.6_ Tm maximum
d) The maximum particle rate in the focal plane is 6 kHz when the CRDC detectors are being used. What is the maximum total particle rate expected in the S800 focal plane?
_6 k _ Hz

Beam Request Worksheet Instructions

Please use a separate worksheet for each distinct beam-on-target requested for the experiment. Do not forget to include any beams needed for calibration or testing. This form does not apply for experiments based in the A1900. Note the following:

(a) **Beam Preparation Time** is the time required by the NSCL for beam development and beam delivery. This time is calculated as per item 4. of the Notes for PAC 31 in the Call for Proposals. This time is not part of the time available for performing the experiment.

(b) **Beam-On-Target Time** is the time that the beam is needed by experimenters for the purpose of performing the experiment, including such activities as experimental device tuning (for both supported and non-supported devices), debugging the experimental setup, calibrations, and test runs.

(c) The experimental device tuning time (XDT) for a supported device is calculated as per item 5. of the Notes for PAC 31 in the Call for Proposals. For a non-supported device, the contact person for the device can help in making the estimate. In general, XDT is needed only once per experiment but there are exceptions, e.g. a change of optics for the S800 will require a new XDT. When in doubt, please consult the appropriate contact person.

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

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

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

(g) For rare-isotope beam experiments, please remember to send an electronic copy of the LISE++ files used to obtain intensity estimates.

Beam Request Worksheet

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

	Beam Preparation Time	Beam-On-Target Time
	18	84

Primary Beam (from beam list)

Isotope	124 Sn	
Energy	120	MeV/nucleon
Minimum intensity	1.5	particle-nanoampere

Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet): 14 hrs

Beam-On-Target

Isotope	124 Sn	
Energy	50	MeV/nucleon
Rate at A1900 focal plane	.1 pnA	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	1%	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity	99	%
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator
	[ ]	Timing start signal from A1900 extended focal plane

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

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: 18 hrs

Experimental device tuning time [see note (c) above]: 36 hrs
S800 [] SeGA [ ] Sweeper [ ] Other [X]
On-target time excluding device tuning: 48 hrs

Total on-target time for this beam: 84 hrs

Beam Request Worksheet

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

	Beam Preparation Time	Beam-On-Target Time
	18	24

Primary Beam (from beam list)

Isotope	118 Sn	
Energy	120	MeV/nucleon
Minimum intensity	1.5	particle-nanoampere

Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet): 14 hrs

Beam-On-Target

Isotope	118 Sn	
Energy	50	MeV/nucleon
Rate at A1900 focal plane	.1 pnA	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	1%	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity	99	%
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator
	[ ]	Timing start signal from A1900 extended focal plane

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

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: **18 hrs**

Experimental device tuning time [see note (c) above]: 0 hrs
S800 [ ] SeGA [ ] Sweeper [ ] Other [ ]
On-target time excluding device tuning: 24 hrs

Total on-target time for this beam: **24 hrs**

Beam Request Worksheet

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

	Beam Preparation Time	Beam-On-Target Time
	18	48

Primary Beam (from beam list)

Isotope	112 Sn	
Energy	120	MeV/nucleon
Minimum intensity	1	particle-nanoampere

Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet): 14 hrs

Beam-On-Target

Isotope	112 Sn	
Energy	50	MeV/nucleon
Rate at A1900 focal plane	.1 pnA	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	1	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity	99	%
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator
	[ ]	Timing start signal from A1900 extended focal plane

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

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: 18 hrs

Experimental device tuning time [see note (c) above]: 0 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
	18	16

Primary Beam (from beam list)

Isotope	Kr 78	
Energy	150	MeV/nucleon
Minimum intensity	25	particle-nanoampere

Tuning time (14 hrs; 0 hrs if the beam is already listed in an earlier worksheet): 14 hrs

Beam-On-Target

Isotope	p,α, fragments	"Cocktail"
Energy	80	MeV/nucleon (protons)
Rate at A1900 focal plane	2000	pps/pnA (secondary beam) or pnA (primary beam)
Total A1900 momentum acceptance	1	% (e.g. 1%, not ±0.5%)
Minimum Acceptable purity		%
Additional requirements	[ ]	Event-by-event momentum correction from position in A1900 Image 2 measured with [ ] PPAC [ ] Scintillator
	[ ]	Timing start signal from A1900 extended focal plane

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

Tuning time to vault: 4 hrs

Total beam preparation time for this beam: 18 hrs

Experimental device tuning time [see note (c) above]: 0 hrs
S800 [ ] SeGA [ ] Sweeper [ ] Other [ ]
On-target time excluding device tuning: 12 hrs

Total on-target time for this beam: 12 hrs