TRIUMF - RESEARCH PROPOSAL	Experiment no. 1057	Sheet 1 of 17

Title of proposed experiment

Investigation on ground state structure in the mirror pair ^{9}C-^{9}Li

Name of group

Spokesperson for group

Rituparna Kanungo

Email address

ritu@triumf.ca

Members of group (name, institution, status)

(For each member, include percentage of research time to be devoted to this experiment over the time frame of the experiment)

A. Andreyev	TRIUMF	Research Associate	10 %
G. Ball	TRIUMF	Research Scientist	5 %
L.Buchmann	TRIUMF	Research Scientist	10 %
B. Davids	TRIUMF	Research Scientist	5%
G. Hackman	TRIUMF	Research Scientist	10%
R. Kanungo	TRIUMF	Research Associate	40 %
J. Pearson	McMaster University	Postdoctoral fellow	15 %
C. Ruiz	TRIUMF & Simon Fraser University	Research Associate	15 %
G. Ruprecht	TRIUMF	Research Associate	15 %
J.P. Schiffer	Argonne National Lab.	Professor,Scientist	5 %
A. Shotter	TRIUMF	Director	20 %
I. Tanihata	Argonne National Lab	Professor,Scientist	15 %
P. Walden	TRIUMF	Research Scientist	25 %

Start of preparations: August 2006 onwards

Date ready:

February 2006 onwards(tentative)

Completion date:

July 2006

Beam time requested:

12-hr shifts	Beam line/channel	Polarized primary beam?
36	TUDA	No
36	ISACII	No

SUMMARY

Do not exceed one page.

Over the past few years studies of neutron-rich nuclei have clearly showed re-ordering of nucleon orbitals, thereby implying changes in shell closure. Investigation of proton-rich nuclei have so far been limited mainly because it was believed that such re-ordering may not take place due to the Coulomb barrier. Very recently however, lowering of the $2s_{1/2}$ orbital has been found in fragmentation studies of ^{17}Ne. Further evidence of lowering exists in the unbound resonant states of its neighbouring nuclei. The possibility of mirror symmetry breaking in the ground states of ^{17}Ne and ^{17}N was also pointed out.

Following the same T_z=-3/2 chain down to the lightest bound nucleus, ^{9}C, one observes that the isoscalar magnetic moment of the mirror pair ^{9}C-^{9}Li shows an anomalously large value $\langle\sigma\rangle = 1.44$. This has not found a satisfactory explanation so far. There is a possibility that such an anomaly may arise due to the presence of an intruder orbital ($2s_{1/2}$) in the ground state of ^{9}C. Evidence for that is yet to be found. Thus, to address this question one needs to study the ground state configuration of ^{9}C and ^{9}Li. In a core + proton (neutron) model of these nuclei, this would mean that we need to find the amplitudes of the different configurations where the 'core' nucleus is in its different states coupled to the valence proton (neutron) in different orbitals. For ^{9}C the core nucleus is ^{8}B while ^{9}Li has a core of ^{8}Li.

The presence of an intruder ($2s_{1/2}$) orbital necessarily requires the core (^{8}B or ^{8}Li) to be in a negative parity state. The ground state of ^{8}B and ^{8}Li is a positive parity 2^+ state. Looking into the excited states of these 'core' nuclei (which are T=1 mirror pairs) a remarkable asymmetry is seen for the resonance states near 3 MeV. While ^{8}Li has a 1^+ resonance (Γ=1 MeV) at 3.1 MeV, its mirror partner ^{8}B has a 2^- resonance ($\Gamma\sim$ 4 MeV) at 3.5 MeV. Thus, if the ground state of ^{9}C can be found to contain an admixture of ^{8}B in its 2^- state, then one can conclude the associated valence proton occupies the intruder $2s_{1/2}$ orbital.

We therefore aim to determine the different components of the ^{8}B+proton and ^{8}Li+neutron configurations in the ground states of ^{9}C and ^{9}Li respectively. These can be investigated by one-proton transfer from ^{9}C and one-neutron transfer from ^{9}Li through the $d(^{9}\mathrm{C},^{3}\mathrm{He})^{8}\mathrm{B}$ and $d(^{9}\mathrm{Li},t)^{8}\mathrm{Li}$ reactions. The light ejectiles ^{3}He and t as well as the heavy residues will be detected by the annular silicon detector array.

BEAM and SUPPORT REQUIREMENTS

Experimental area

1. TUDA beamline, ISAC1
2. ISACII

Primary beam and target (energy, energy spread, intensity, pulse characteristics, emittance

Secondary channel

Secondary beam (particle type, momentum range, momentum bite, solid angle, spot size, emittance, intensity, beam purity, target, special characteristics)

Particle type : $^{9}C\ (3^{+})$, $^{9}Li(2^{+})$, $^{8}Li(2^{+})$

Energy = ^{9}C: 1.8 A MeV (5A MeV at ISACII) and ^{9}Li : 1.68A MeV (5A MeV at ISACII)

^{8}Li : 0.98A MeV and 1.6A MeV (3.0A MeV, 4.2A MeV at ISACII)

Spot size on target = ±1mm (X and Y)

Intensity of secondary beam on reaction target

^{9}C : ~ 10^{4}/sec (minimum) we may use higher intensity if that is available for ^{9}C.

^{9}Li : 10^{5}/sec

^{8}Li : 10^{6}/sec

TRIUMF SUPPORT:
Summarize all equipment and technical support to be provided by TRIUMF. If new equipment is required, provide cost estimates.

NOTE: Technical Review Forms must also be provided before allocation of beam time.

Appropriate ion source and target for ^{9}C beam

Construction of support for mounting a plastic scintillator detector.

Purchase of two photo-multiplier tubes (preferably ultra-fast ones) and scintillator.

NON-TRIUMF SUPPORT:
Summarize the expected sources of funding for the experiment.
Identify major capital items and their costs that will be provided from these funds.

SAFETY

Summarize possible hazards associated with the experimental apparatus, precautions to be taken, and other matters that should be brought to the notice of the Safety Officer. Details must be provided separately in a safety report to be prepared by the spokesperson under the guidance of the Safety Report Guide available from the Science Division Office.

There are no major safety hazards in this experiment.

1. Introduction

The Coulomb energy differences between the $s_{1/2}$ state and other states leads to asymmetry in the spectra of mirror nuclei , termed the Thomas-Ehrmann shift. This is clearly observed in the $1/2^+$ excited states of the ^{17}O-^{17}F and ^{13}C-^{13}N pairs [1]. The $2s_{1/2}$ orbit is thus lowered in proton-rich nuclei compared to its mirror partner. Lowering of the $2s_{1/2}$ orbital has recently been discussed in ^{17}Ne leading to the possibility of a two-proton halo in this nucleus [2].

The T_z=±3/2 mirror pair, ^{9}C-^{9}Li is a another particularly interesting case for investigation, because the magnetic moment of ^{9}C shows an anomalous quenching (-1.3914μ_N with respect to single particle value –1.91 μ_N). The isoscalar spin matrix element $\langle\sigma\rangle$, of this mirror pair, shows an anomalously large value of 1.44 [3,4]. This large deviation from the usual value of unity has not yet found a reasonable explanation. Inclusion of isospin non-conserving terms could account for only half of the anomaly [4]. A re-normalisation of the nuclear magneton leading to a change of g-factors was proposed as another possible source for this anomaly, which is however not fully confirmed [2,5]. Recently, yet another suggestion of shell quenching in ^{9}C, bringing in intruder orbitals (mainly the $2s_{1/2}$ orbital), has been put forward by Utsuno [6]. This will then lead to mirror asymmetry in the ground states of ^{9}C and ^{9}Li; such asymmetry has been discussed to account for the anomalous magnetic moment. About 40% intruder orbital mixing in ^{9}C has been suggested [6]. However, there has been no experimental investigation searching for intruder orbital mixing in the ground state configurations of ^{9}C and ^{9}Li.

It is therefore, important and interesting to investigate the amplitudes of the different configurations which constitute the ground states of ^{9}C and ^{9}Li. Knowledge of the ^{9}C and ^{9}Li ground state is at present confined to only one component, with ^{8}B(^{8}Li) core in its ground state. Studies on ^{9}C exploring the asymptotic normalization coefficient have been done using using the ^{8}B(d,n)^{9}C reaction [7], capture reaction [6] and proton knockout reaction [9]. These have finally yielded the ANC value of 1.27 fm^{-1}. The neutron spectroscopic factors for ^{9}Li were very recently measured using d(^{8}Li,p)^{9}Li reaction [10].

One needs to know however the amplitudes of the other components with ^{8}B(^{8}Li) in the excited states to obtain a complete picture of the ground states of these nuclei. The one nucleon transfer reaction is one of the best suited tools for this purpose. We thus, propose to investigate the one-proton transfer from ^{9}C by using the reaction d(^{9}C,^{3}He)^{8}B. The mirror nucleus, ^{9}Li will be investigated by d(^{9}Li,t)^{8}Li reaction in which one neutron will be transferred. The presence of any intruder (s-orbital) mixing in the ground state of ^{9}C (and/or ^{9}Li) will lead to the observation of a negative parity excited state (resonance) in ^{8}B(and/or ^{8}Li). The nucleon transfer from the expected normal p-orbitals in ^{9}C(^{9}Li) on the other hand will populate positive parity levels in ^{8}B(and ^{8}Li).

It is interesting to note here that ^{8}B and ^{8}Li show an asymmetry in spin assignment for the resonance around 3 MeV. While the level in ^{8}B at 3.5 MeV (Γ~4 MeV) is 2^- [11], the level at 3.21 MeV(Γ~1 MeV) in ^{8}Li is found to be 1^{+} [12]. There exists some controversy on the existence of the 2^{-} state in ^{8}B [13]. It is necessary to investigate if these levels are populated by single nucleon transfer from ^{9}C and ^{9}Li respectively. This, as mentioned before, will also confirm if there exists any intruder orbital mixing in ground state of $^{9}C(^{9}Li)$ and its parentage. It maybe mentioned here that in order to account for a good polarization in the neutron scattering from ^{7}Li, a 2^{-} level has been suggested at $^{8}Li^{*} \sim 5.4$ MeV and a 3^{-} level is suggested at higher energy. It is discussed later that due to the large width of the resonances, proper angular distributions are difficult to obtain for these resonances.

It is also interesting to note that a very large asymmetry has been observed for beta decay branches to the 12.16 MeV level of ^{9}B (from $^{9}C(\beta^{+})$) and 11.81 MeV level in ^{9}Be (from $^{9}Li(\beta^{-})$) [14,15]. This asymmetry, $\delta = B_{GT}^{-}/B_{GT}^{+} - 1 = 3.4(10)$ [15] has not yet been understood. The decays to the ground states of the daughter nuclei however do not show any asymmetry. Thus, the asymmetry may be due to differences in the nature of excited states in the daughter nuclei, but could as well be related to differences in the ground states of the two nuclei [15].

References :

[1] R.G. Thomas, Phys. Rev. C 88 (1952) 1109; J.B. Ehrmann, Phys. Rev. C 81 (1951) 412.

[2] R. Kanungo et al, Phys. Lett. B 571 (2003) 21.

[3] K. Matsuta et al, Nucl. Phys. A 704 (2002)98c.

[4] M. Huta et al, Phys. Rev. C 57 (1998) R2790; B.A. Brown Prog. Part. Nucl. Phys. 47 (2001) 517.

[5] S. Ichii et al, Nucl. Phys. A 464 (1987) 575.

[6] Y. Utsuno, Phys. Rev. C 70 (2004) 011303R.

[7] D. Beaumel et al, Phys. Lett. B 514 (2001) 226.

[8] R.E.Tribble et al, Nucl. Phys. A 718 (2003) 147c.

[9] J. Enders et al, Phys. Rev. C 67 (2003) 064301.

[10] A.H. Wusomaa et al, Phys. Rev. Lett. 94 (2005) 082502.

[11] G.V. Rogachev et al, Phys. Rev. C 64 (2001) 061601R.

[12] M.J.G. Borge et al, Nucl. Phys. A 560 (1993) 664.

[13] C. Angulo et al, Nucl. Phys. A 716 (2003) 211.

[14] U.C.Bergmann et al, Nucl. Phys. A 692 (2001) 427.

[15] M.J.G. Borge et al, Nucl. Phys. A 738 (2004) 206.

2. Description of experiment

The experiment will be performed using radioactive beams of ^{9}Li and ^{9}C at the energies mentioned above. The maximum energy available at ISAC1 with maximum yield at reaction target has been chosen for the first step of the investigation. This will provide us with the first signature of an intruder s-orbital in ^{9}C, if any. We plan to study the energy dependence of the reaction to confirm that the parentages of the different configurations for ^{9}C and ^{9}Li deduced from the data have no reaction dependent effects. For this, at the second stage of the experiment we will perform the same study at a higher energy typically (~ 5*A* MeV) at ISACII.

A 1μm thick $(CD_2)_n$ foil will serve as the deuteron target. The choice of the thickness is based on minimizing energy loss, energy straggling, and multiple scattering in the target. After the reaction in the target, the detection of both light ejectiles (i.e. target-like residues) as well as the heavy recoils (i.e. projectile-like residue) is necessary for clear identification of the reaction channel of interest. This will be accomplished by using annular silicon strip detectors (3 full LEDA arrays + 1 CD detector). The schematic setup is shown in Fig.1. The excitation energy spectrum for the resonances in ^{8}B (^{8}Li) will be obtained from the measured energy and angle of the light ejectiles i.e. ^{3}He (t) from the silicon detectors placed at 8cm. The heavy residue will be detected by the silicon detectors (LEDA+CD) placed at ~ 22-23cm. The light ejectiles will also be registered in these detectors. The deuterons from elastic scattering will be detected at these forward angles. This will be done with a combination of the silicon detectors and the plastic scintillator. The LEDA silicon detectors are typically 300μm thick, while the CD silicon detector is 500 μm thick.

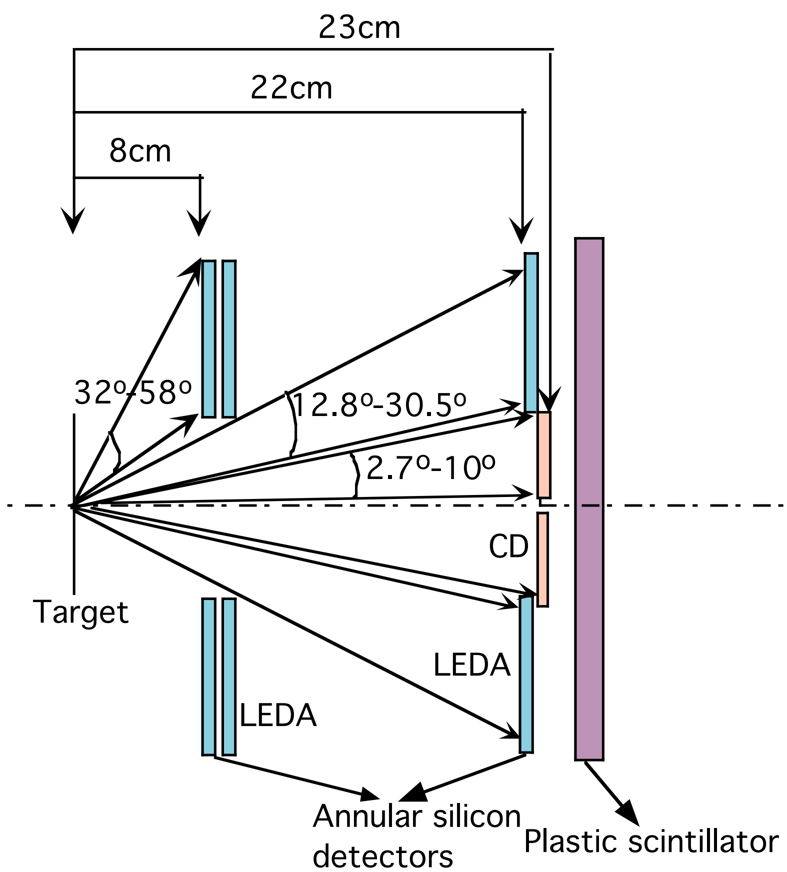

Fig.1 Schematic view of the experimental setup

3. Reaction characteristics and simulation of particle identification

Figure 2 shows the kinematic loci for the $d(^9C, {}^3He)^8B$ reaction at E_{lab}=1.8*A* MeV. The reaction $d(^9Li,t)^8Li$ has the same characteristics and is thus not discussed separately here. The width of the resonances in ^8B have been considered here. The colour of the curves correspond to channels with ^8B in its different states as indexed in Fig.2a. The elastic and inelastic scattering of ^9C from deuterons is also shown. The colour coding will be same for the rest of the discussion presented here. Fig.2b shows the energy and scattering angle correlation in the laboratory frame for the heavy beam-like residues (which in case of resonance states are the heavy decay products). The third excited state in ^8B ($^8B_3$*) is the 2^- state and if observed will indicate the proton to be in the intruder ($2s_{1/2}$) orbital in ^9C. We aim to detect and measure the energy and scattering angle of ^3He at forward laboratory angles [θ_{lab} = 32 deg – 58 deg]. This corresponds to [θ_{cm} = 30 deg – 110 deg] for the 2^- excited state in ^8B and θ_{cm} = 80 deg – 125 deg for ground state of ^8B.

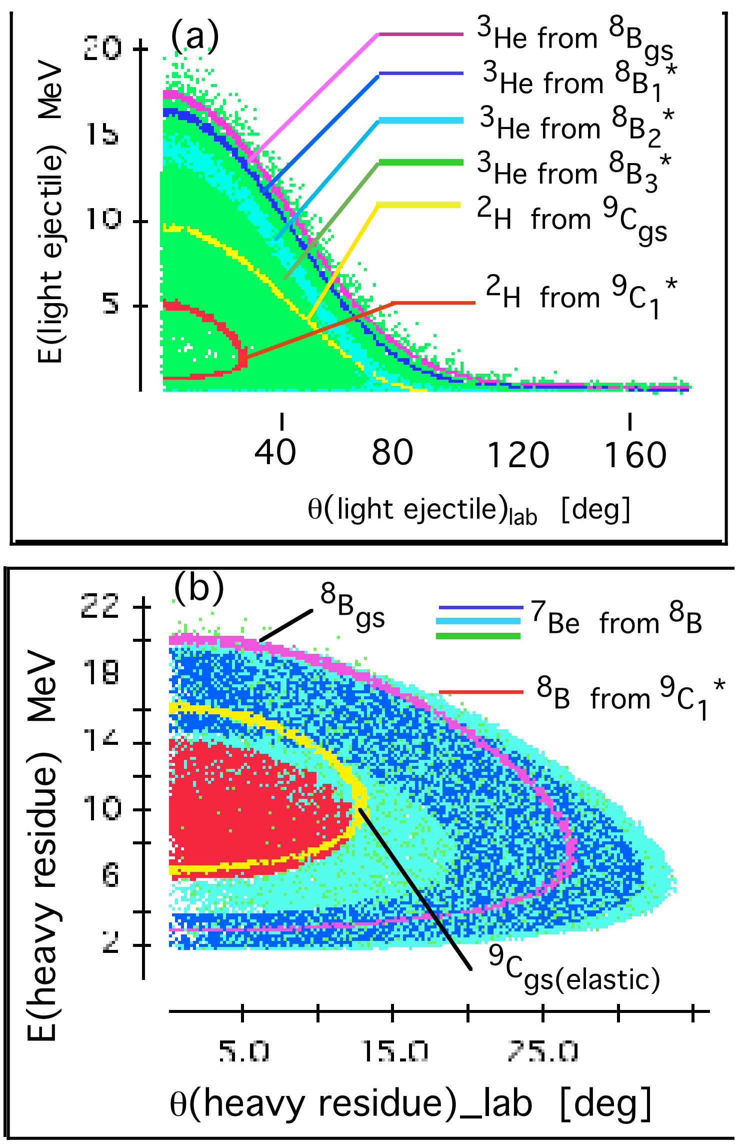

Fig.2 Kinematic loci for the (a) light ejectile and (b) the heavy residues.

The main sources of background arise from elastic and inelastic scattering of ^9C on deuterons and ^{12}C in the CD_2 target. Apart from this, there maybe one-nucleon transfer reactions on ^{12}C (in CD_2 target) which will give rise to ^{13}N. These however can be clearly eliminated by identifying both the light-ejectile (^3He) and the heavy residue (^8B or ^7Be from decay of ^8B*) for the reaction of interest.

The energies of the recoils (both light and heavy particles) being very low, particle identification (PID) by ΔE-E would require a very thin ΔE detector (~ 10μm). Since we do not have such an annular detector array at present, we aim to perform particle identification (PID) using the correlation between time-of-flight and the total energy. The total energy will be measured by the silicon detectors. The time-of-flight will be measured between the RF signal from the cyclotron and the silicon detector.

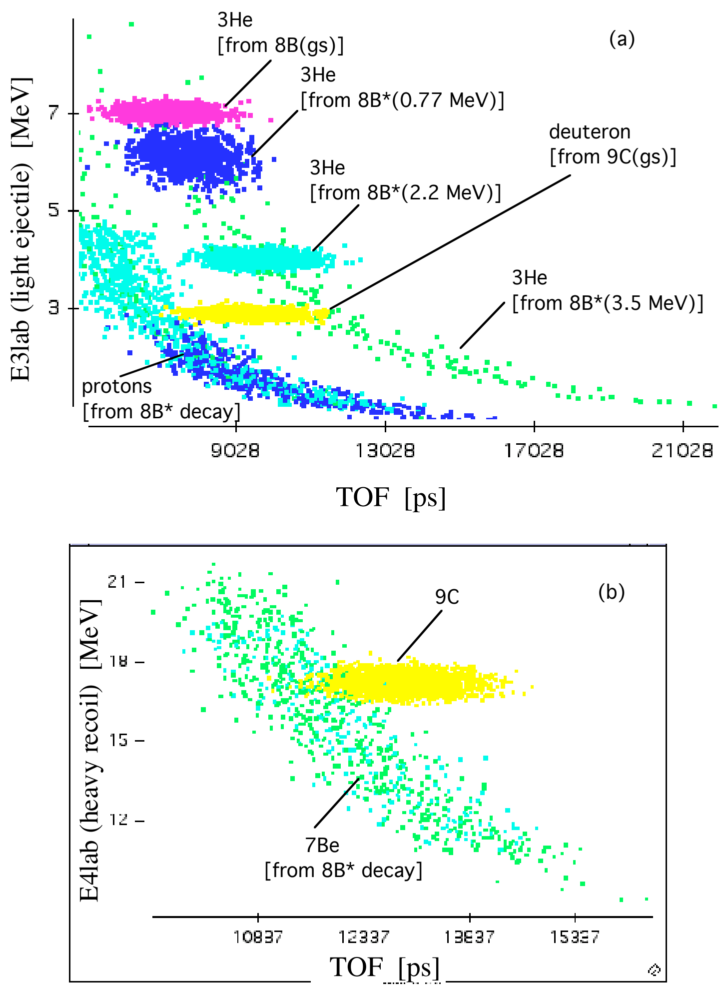

Fig.3 Simulation results showing PID of light ejectile and heavy recoil. Details are discussed in the text.

Fig.3 shows the monte-carlo simulation of PID for one radial strip selected in the silicon detector for the light ejectiles located closest to the target. The different colours refer to the different reactions shown in Fig.2. The simulation assumed a 0.5% energy spread (σ) of the beam and an RF time resolution of 500ps(σ). This is a rather conservative estimate compared to the longitudinal emittance of ISAC1. The silicon detector has been assumed to have a time resolution of 500ps(σ) and an energy resolution of 2% (fwhm). The figure includes effects of energy loss, straggling and multiple scattering in the target. The angular broadening of ^{3}He from multiple scattering is at maximum ~ 1.5mrad (σ). It is seen in Fig.3a that protons emitted from decay of the unbound excited states in ^{8}B can be clearly separated from the ^{3}He. In some cases, the deuteron background from elastic scattering may not be separated from ^{3}He by the light particle detector alone. In this case we will look for the coincidence with the heavy particle detector as shown in Fig.3b.

It can be seen that the separation of ^{9}C and ^{7}Be will allow us to eliminate a large part of the elastic scattering. Since the figure here shows the sum of all pixels (theta and phi strips) in the heavy particle detector, so some small part of ^{9}C still remains un-separated from ^{7}Be. That can be reduced further by analyzing each pixel in the heavy particle detector. The main problem in clear PID will arise from the width (Γ~4 MeV) of the 2^- resonance of ^{8}B. We will be able to clearly identify the upper half of the resonance, while the lower half will mix in with the lower excited states of ^{8}B. Thus, we will estimate the counts for the lower half based on curve fitting in comparison to simulated results.

The carbon background from CD_2 target can be clearly separated from light ejectiles in the LEDA detectors close to the target. For this detector, C- elastic scattering in the range θ_{cm} = 60 deg-110 deg contributes. Thus the elastic scattering rate is not expected to be high. On the other hand in the heavy recoil detector we will have ^{9}C from elastic scattering θ_{cm} = 2.7 deg – 10 deg. This will imply a higher event rate. The Rutherford cross section for elastic scattering from C is ~ 0.2x10^8 mb/sr. Assuming a beam intensity of 10^5/sec, the maximum rate per sector in the first strip of the CD detector is ~ 12 counts/sec. One may need to accommodate 2-3 times higher rate than this which can arise from decay of the implanted nuclei in the detector. It thus seems that the present beam intensity does not pose any high rate related problem in the detector. The detector setup can accommodate ~10 times higher intensity for this study. This upper limit on the allowable beam intensity will be dictated by the data acquisition rate, which at present is ~ 3kHz with minimal dead time. The beam intensity will be derived from the elastic scattering cross section at the forward angle. For the first two strips of the CD silicon detector, the Rutherford scattering dominates giving us the absolute normalization.

The elastic scattering of ^{9}C+d and ^{9}Li+d will be measured simultaneously with the transfer reaction(s) of interest during the main part of the experiment. This data will be used for deriving the optical potential parameters for the entrance channel. In order to have some guidance on the exit channel parameters, we will perform elastic scattering using a ^{8}Li beam at two different energies, 1.6A MeV (which is close to that for ^{9}C experiment condition) and 0.98A MeV (which is for ^{9}Li experiment condition). We will use $(CH_2)_n$ and $(CD_2)_n$ targets for this and extrapolate to potentials for t (^{3}He). Alternatively, we are considering possibility of using a ^{3}He target which however is not confirmed at the moment.

4. Count rate and beam time request

The ^{9}C beam was produced at TISOL at TRIUMF with an intensity of 10^4/sec with a proton beam current of 1μA. It is yet to be produced and accelerated at ISAC facility and a quick development of this is needed. For the present estimate we assume the ^{9}C beam intensity of 10^4/sec on the reaction target.

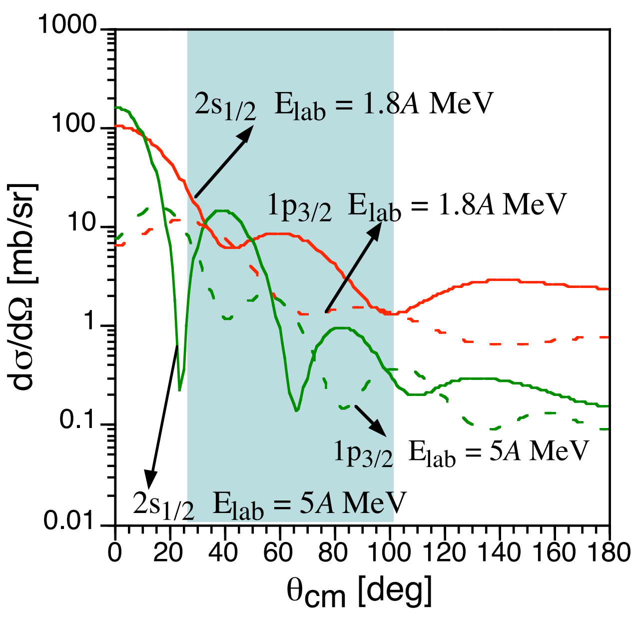

Fig.4 Angular distribution for the 3.5 MeV resonance in ^{8}B in the DWBA framework.

The expected statistics have been estimated based on DWBA calculations shown in Fig.4. Variation of optical potential parameters was done to check the uncertainty in the cross section. Based on this study the number of counts which can be obtained within the solid angle covered (shaded region in Fig.4) by the light ejectile LEDA detector is shown below. The $(CD_2)_n$ foil thickness of 1μm is considered for this estimate.

Nucleus	Resonance	Beam intensity	Counts [sum of 16 strips]	Days	Wave	Spectroscopic factor
^{9}C	3.5 MeV	10^4/sec	400*	10	s-wave	0.4
^{9}Li	3.2	10^5/sec	1200	5	p-wave	0.1
^{9}Li	3.2	10^5/sec	1400	5	s-wave	0.1
^{9}Li	0.0	10^5/sec	500	5	p-wave	0.6

Due to the large width of the resonance around 3 MeV we will not be able to measure a meaningful angular distribution with 10^4/sec intensity. Thus, the beam-time request is based on obtaining a reasonable number of integrated counts for the different states in each strip of the silicon detector. The counts for 3.5 MeV resonance (which is related to the putative intruder orbital) are estimated assuming the spectroscopic factor suggested in Ref.[6]. The measuring time however should be long enough to detect spectroscopic factors as small as 0.1. For ^{9}Li we will try to use the higher intensity to have sufficient statistics to try out possible ways of obtaining the angular distribution shape for the resonance around 3 MeV.

The following table shows the total beamtime request for first phase of the experiment :

Measurement type	Energy	Days
^{9}C (3^+)	1.8 *A* MeV	10 (data taking)
$^{9}Li(2^+)$	1.68 *A* MeV	5 (data taking)
^{8}Li	1.0 *A* MeV	1
^{8}Li	1.6 *A* MeV	1
Electronics adjustment(for each beam) and DAQ check		1 (in total)

We request a total of 18 days (=36 shifts) of beamtime at ISAC1. Similar amount of beamtime will be required for the second phase of the experiment at ISACII for the beam energy region ~ 5*A* MeV.

The beamtime request shown above does not include time for yield measurement of the radioactive beams or beam tuning to the reaction target for any of the beams. The time for primary beam (OLIS beam) tuning is also not considered in this estimate. This should typically be one day for each beam energy. We wish to take some data during the primary beam tuning.

While, it would be ideal to run the entire experiment in one setting, it is not a strict limitation. The part of the experiment using lithium beams can be performed close to the time of other experiments using similar beams.

5. Data analysis

The analysis of the data will be performed using personal computers presently available at TRIUMF.

6. Readiness

The main development necessary for the success of the experiment is the ^{9}C beam with minimum 10^4/sec intensity at the reaction target (one order higher magnitude is preferred). A quick development of this beam is requested.

A plastic scintillator detector needs to be mounted in the TUDA chamber which may take few months.

1. Search for an isomeric state in ^{19}C

   R. Kanungo, Z.Elekes H. Baba, , Zs. Dombrádi, Zs. Fülöp, J. Gibelin, Á. Horváth, Y. Ichikawa, E. Ideguchi, N. Iwasa, H. Iwasaki, S. Kawai, Y. Kondo, T. Motobayashi, M. Notani, T. Ohnishi, A. Ozawa, H. Sakurai, S. Shimoura, E. Takeshita, S. Takeuchi, I. Tanihata, Y. Togano[3], C. Wu, Y. Yamaguchi, Y. Yanagisawa, A. Yoshida, K. Yoshida

   Nucl. Phys. A (in press)

2. Low-lying excited states in $^{17,19}C$

   Z.Elekes , Zs. Dombrádi, R. Kanungo, H. Baba, Zs. Fülöp, J. Gibelin, Á. Horváth, Y. Ichikawa, E. Ideguchi, N. Iwasa, H. Iwasaki, S. Kawai, Y. Kondo, T. Motobayashi, M. Notani, T. Ohnishi, A. Ozawa, H. Sakurai, S. Shimoura, E. Takeshita, S. Takeuchi, I. Tanihata, Y. Togano[3], C. Wu, Y. Yamaguchi, Y. Yanagisawa, A. Yoshida, K. Yoshida

   Phys. Lett. B 614 (2005) 174

3. Excited states in neutron-rich boron isotopes

   R. Kanungo, Z.Elekes , H. Baba, Zs. Dombrádi, Zs. Fülöp, J. Gibelin, Á. Horváth, Y. Ichikawa, E. Ideguchi, N. Iwasa, H. Iwasaki, S. Kawai, Y. Kondo, T. Motobayashi, M. Notani, T. Ohnishi, A. Ozawa, H. Sakurai, S. Shimoura, E. Takeshita, S. Takeuchi, I. Tanihata, Y. Togano[3], C. Wu, Y. Yamaguchi, Y. Yanagisawa, A. Yoshida, K. Yoshida

   Phys. Lett. B 608 (2005) 206

4. Neutron removal studies on ^{19}C

   M. Chiba, R. Kanungo, B. Abu-Ibrahim, S. Adhikari, D. Fang, N. Iwasa, K. Kimura, K. Maeda, S. Nishimura, T. Ohnishi, A. Ozawa, C. Samanta, T. Suda, T. Suzuki, Q. Wang, C. Wu, Y. Yamaguchi, K. Yamada, A. Yoshida, T. Zheng, I. Tanihata

   Nucl. Phys. A 741 (2004) 29

5. Study of the reaction cross section of ^{17}C from reaction cross section measurement

   Cuie Wu, Y. Yamaguchi, A. Ozawa, R. Kanungo, I. Tanihata, T. Suzuki, D.Q. Fang, T. Suda, T. Ohnishi, M.Fukuda, N.Iwasa, T.Ohtsubo, T. Izumikawa, R. Koyama, W. Shinozaki, M. Takahashi

   Nucl. Phys. A 739 (2004) 3

6. One- and two-proton removal from ^{15}O

   H.Jeppesn, R. Kanungo, B. Abu-Ibrahim, S. Adhikari, M.Chiba, D. Fang, N.Iwasa, K. Kimura, K. Maeda, S. Nishimura, T. Ohnishi, A. Ozawa, C. Samanta T. Suda, T. Suzuki, I. Tanihata, Q. Wang, C. Wu, Y. Yamaguchi, K. Yamada, A. Yoshida, T. Zheng

   Nucl. Phys. A 739 (2004) 57

7. Two-proton halo in ^{17}Ne

   Rituparna Kanungo

Nucl. Phys. A 738 (2004) 293

8. Neutron configuration of ^{16}C studied via one- and two-neutron removal momentum distributions

T. Yamaguchi, T. Zheng, A. Ozawa, M. Chiba, R. Kanungo, T. Kato, K. Morimoto, T. Ohnishi, T. Suda, Y. Yamaguchi, A. Yoshida, K. Yoshida and I. Tanihata

Nucl. Phys. A 734 (2004) E73

9. Two-proton halo in ^{17}Ne

R. Kanungo

Nucl. Phys. A 734 (2004) 337

10. Production and decay properties of $^{272}111$ and its daughter nuclei

K. Morita, K. Morimoto, D. Kaji,, H. Haba, E. Ideguchi, J.C.Peter, R. Kanungo, K. Katori, H. Koura, H. Kudo, T. Ohnishi, A. Ozawa, T. Suda, K. Sueki, I. Tanihata, H. Xu, A.V. Yeremin, A. Yoneda, A. Yoshida, Y.-L. Zhao and T. Zheng, S. Goto, F. Tokanai

Jour. Phys. Soc. Jpn. 73 (2004) 1738

11. Status of superheavy element research using GARIS, RIKEN

K. Morita, K. Morimoto, D. Kaji, S. Goto, H. Haba, E. Ideguchi, R. Kanungo, K. Katori, H. Koura, H. Kudo, T. Ohnishi, A. Ozawa, J.C.Peter, T. Suda, K. Sueki, I. Tanihata, F. Tokanai, H. Xu, A.V. Yeremin, A. Yoneda, A. Yoshida, Y.-L. Zhao and T. Zheng

Nucl. Phys. A 734 (2004) 101

12. One neutron halo structure in ^{15}C

D.Q. Fang, T. Yamaguchi, T. Zheng, A. Ozawa, M. Chiba, R. Kanungo, T. Kato, K. Morimoto, T. Ohnishi, T. Suda, Y. Yamaguchi, A. Yoshida, K. Yoshida, and I. Tanihata

Phys. Rev. C. 69 (2004) 034613

13. Possibility of a two-proton halo in ^{17}Ne

R. Kanungo, M. Chiba, S. Adhikari, D. Fang, N. Iwasa, K. Kimura, K. Maeda, S. Nishimura, Y. Ogawa, T. Ohnishi, A. Ozawa, C. Samanta, T. Suda, T. Suzuki, Q. Wang, C. Wu, Y. Yamaguchi, K. Yamada, A. Yoshida, T. Zheng, I. Tanihata

Phys. Lett. B. 571 (2003) 21

14. Halo and skin nuclei.

Isao Tanihata and Rituparna Kanungo

C.R. Physique 4 (2003) 437

15. Experimental evidence for ^{7}H and for a specific structure of ^{8}He.

A.A. Korshennikov, E.Yu. Nikolskii, E.A. Kuzmin, A. Ozawa, K. Morimoto, F. Tokanai, R. Kanungo, I. Tanihata, N.K. Timofeyuk, M.S. Golovkov, A.S. Fomichev, A.M. Rodin, M.L.

Chelnokov, G.M. Ter-Akopian, W. Mittig, P. Roussel-Chomaz, H. Savajols, E. Pollacco, A.A. Ogloblin, M.V. Zhukov

Phys. Rev. Lett. 90 (2003) 082501

16. Nuclear shell changes at the limit of stability

    Rituparna Kanungo

    Nucl. Phys. A 722 (2003) 30c

17. Measurement of one- and two-neutron transfers in reaction of 6He+9Be at 25 MeV/u

    Y.-C.Ge, Y.-L. Ye, T. Zheng, Q.-J. Wang, Z.-H. Li, X.-Q. Li, D.-X.Jiang, A. Ozawa, Y. Yamaguchi, C. Wu, R. Kanungo, D. Fang and I. Tanihata

    Chin. Phys. Lett. 20(2003) 1034

18. Reply to Comment on : Experimental evidence of core modification in the near drip-line nucleus ^{23}O.

    Rituparna Kanungo, Masami Chiba, Naohito Iwasa, Shunji Nishimura, Akira Ozawa, Chhanda Samanta, Toshimi Suda, Takeshi Suzuki, Takayuki Yamaguchi, Tao Zheng, Isao Tanihata

    Phys. Rev. Lett 90 (2003) 159202

19. Momentum distribution of ^{14}C and ^{15}C fragments from ^{16}C breakup.

    T. Yamaguchi, T. Zheng, A. Ozawa, M. Chiba, R. Kanungo, T. Kato, K. Morimoto, T. Ohnishi, T. Suda, Y.Yamaguchi, A. Yoshida, K. Yoshida, I. Tanihata

    Nucl. Phys. A 724 (2003) 3

20. Search for ^{21}B.

    A. Ozawa, Y. Yamaguchi, M. Chiba, R. Kanungo, K. Kimura, S. Momota, T. Suda, T. Suzuki, I. Tanihata, T. Zheng, S. Watanabe, T. Yamaguchi, and K. Yoshida

    Phys. Rev. C 47 (2003) 014610

21. Production of neutron rich isotopes by fragmentation of 80MeV/nucleon ^{59}Co beam.

    Le Hong Khiem, T. Kato, K. Morimoto, M. Notani, A. Ozawa, R. Kanungo, I. Tanihata, A. Yoshida

    Phys. Rev. C 722 (2003) 484c.

22. Study of halo stru-3cture of ^{16}C from reaction cross section measurement.

    T. Zheng, T. Yamaguchi, A. Ozawa, M. Chiba, R. Kanungo, T. Kato, K. Katori, K. Morimoto, T. Ohnishi, T. Suda, I. Tanihata, Y. Yamaguchi, A. Yoshida, K. Yoshida, H. Toki, N. Nakajima

    Nucl. Phys. A 709 (2002) 103

23. Momentum distribution of ^{15}B fragments from the breakup of ^{17}B.

T. Suzuki, Y. Ogawa, M. Chiba, M. Fukuda, N. Iwasa, T. Izumikawa, R. Kanungo, Y. Kawamura, A. Ozawa, T. Suda, I. Tanihata, S. Watanabe, T. Yamaguchi, Y. Yamaguchi

Phys. Rev. Lett 89 (2002) 012501

24. Experimental evidence of core modification in the near drip-line nucleus ^{23}O.

Rituparna Kanungo, Masami Chiba, Naohito Iwasa, Shunji Nishimura, Akira Ozawa, Chhanda Samanta, Toshimi Suda, Takeshi Suzuki, Takayuki Yamaguchi, Tao Zheng, Isao Tanihata

Phys. Rev. Lett 88 (2002) 142502

25. Modification of shell structure in unstable nuclei.

Rituparna Kanungo,

Prog. in Theo. Phys. 146 (2002) 422.

26. Halo structure in ^{19}C

Rituparna Kanungo, I. Tanihata, Y. Ogawa, H. Toki, A. Ozawa

Nucl. Phys. A 701 (2002) 378c

27. Observation of new proton and neutron magic numbers

Rituparna Kanungo, I. Tanihata, A. Ozawa

Phys. Lett. B 528 (2002) 58

28. Observation of new proton and neutron magic numbers.

Rituparna Kanungo, I. Tanihata, A. Ozawa

Nuclear Physics in the 21st century, Int. Nucl. Phys. Conf. INPC 2001.AIP Proceedings, 2001, p.741

29. Breakup of 72MeV ^{7}Li projectiles in the fields of ^{12}C and ^{197}Au nuclei

D.Gupta, C.Samanta, R.Kanungo, P.Basu, S.Roy, S.Kailas, A.Chatterjee, B.J.Roy, K.Mahata, A.Samant, and A.Shrivastava

Pramana 57 (2001) 209

30. Possibility of enlarged core structure of N=15 neutron rich nuclei

Rituparna Kanungo, I. Tanihata, A. Ozawa

Phys. Lett. B 512 (2001) 261.

31. Halo structure in ^{19}C : a Glauber model analysis

Rituparna Kanungo, I. Tanihata, Y. Ogawa, H. Toki and A. Ozawa
Nucl. Phys. A 677(2000) 171.

32. Inverse proton scattering from unstable nuclei with halo
Rituparna Kanungo
Proceedings of the RCNP-TMU Symposium, Spins in Nuclear and Hadronic Reactions, World Scientific, 2000, p.183.

33. Effect of smeared ^{4}He-core in ^{6}He+p scattering
D.Gupta, C.Samanta, R.Kanungo
Acta Phys.Pol. B31, (2000) 471

34. Consistent Analysis of Proton Elastic Scattering from $^{4, 6, 8}$He and $^{6, 7, 9, 11}$Li in the Energy Range of 25-75A MeV
D.Gupta, C.Samanta, R.Kanungo
Nucl.Phys. A674, (2000) 77