Edit Original Proposal

TRIUMF — EEC Submission EEC meeting: 201107S *Original Proposal*	TRIUMF	**Exp. No.** S1338 — *In Preparation* **Date Submitted** 2011-06-06 15:20:30

Title of Experiment
Study of nuclear pairing through ^{12}Be(p,t) reaction

Name of Group
Nuclear Reactions

Detailed Information
Complete / merged PDF
Form data only

Spokesperson(s) for Group
R. Kanungo

Current Members of Group

Name	Institution	Status	% of research time devoted to experiment
R. Kanungo	Saint Mary's University	Associate Professor	60%
C. Ruiz	TRIUMF	Research Scientist	30%
B. Davids	TRIUMF	Research Scientist	10%
C. Andreoiu	Simon Fraser University	Assistant Professor	10%
R.A.E. Austin	Saint Mary's University	Assistant Professor	10%
P.E. Garrett	University of Guelph	Professor	10%
I. Tanihata	RCNP/Osaka University	Professor	25%
A. Shotter	TRIUMF/ Edinburgh University	Research Scientist	25%
G. Hackman	TRIUMF	Research Scientist	20%
A.Valencik	Saint Mary's Univ.	Student (Undergraduate)	25%
P. Fortier	Saint Mary's Univ.	Student (Graduate)	25%
J. Atkinson	Saint Mary's Univ.	Student (Undergraduate)	25%
G. Tomney	Saint Mary's Univ.	Student (Undergraduate)	25%
A. Gallant	University of British Columbia	Student (PhD)	20%
R. Kruecken	TU-Munich	Professor	5%
S. Ishimoto	KEK	Research Scientist	25%
H. Savajols	GANIL	Research Scientist	10%
R. Broglia	Milano	Professor	10%

Beam Shift Requests
- 22 shifts on SEBT2/IRIS (unpolarized)

Basic Information

Date submitted
2011-06-06 15:20:30

Date experiment ready

Summary

Investigation of nucleon pairing interaction in regions far from stability is expected to provide new information to define the nuclear interaction in neutron-rich matter. In this proposal we aim to explore the neutron correlation in the A/Z=3 nucleus ^{12}Be. This will be done using the ^{12}Be(p,t) two-neutron transfer reaction.

Study of pairing correlation is also of special interest in understanding the N=8 island of parity inversion and a sub-shell closure at N=6 which should reflect in the population of pairing vibration level in ^{10}Be.

The re-accelerated beam of ^{12}Be energized to 7 MeV/u (presently estimated with an intensity of ~ 400/sec) will be used in conjunction with a hydrogen target.

Plain-text summary

Primary Beamline
BL2A

ISAC Facilities

ISAC facility

ISAC-I facility

ISAC-II facility
SEBT-GPS

Secondary Beam

Isotope(s)
11Li

Energy
7000

Energy units
keVA

Energy spread — maximum

Time spread — maximum

Angular divergence

Spot size
<2

Intensity requested
Highest possible

Minimum intensity
100

Maximum intensity
100000

Charge constraints

Beam purity

Special characteristics

Experiment Support

Beam diagnostics required

Signals for beam tuning

DAQ support

TRIUMF support (resources needed)

NSERC support

Other funding

Muon justification

Safety issues
Use of hydrogen target and standard radiocative sources.

All Proposals and Progress Reports

⟹ **201107S** *(Original Proposal)*

Study of nuclear pairing through ^{12}Be(p,t) reaction

1. Introduction

Pairing interaction in nuclei is one of the key ingredients contributing to the binding of nucleons. The similarity of nucleon pairing with other fermionic systems such as electrons in metals drew the analogy of nuclear pairing interaction to the BCS scheme of superconductivity. While this is somewhat understood for nuclei close to stability, some new features may be prominent in very neutron-rich nuclei. The presence of a neutron surface coupled together with weaker binding energy makes the neutron-rich nuclei an interesting ground for study of pairing correlation.

Recently, the two-neutron transfer from ^{11}Li using the ^{11}Li(p,t) reaction showed a very interesting feature of ^{9}Li being populated in its first excited state for the first time [1]. In the framework of the nuclear field theory this was subsequently interpreted as a direct signature of phonon induced pairing in ^{11}Li [2]. The induced pairing is discussed to be vital in the binding of ^{11}Li since the bare nucleon-nucleon interaction is found to be insufficient to make ^{11}Li bound. The virtual processes associated with the exchange of collective vibrational phonons. In particular the quadrupole vibration of the ^{9}Li core was discussed to be important.

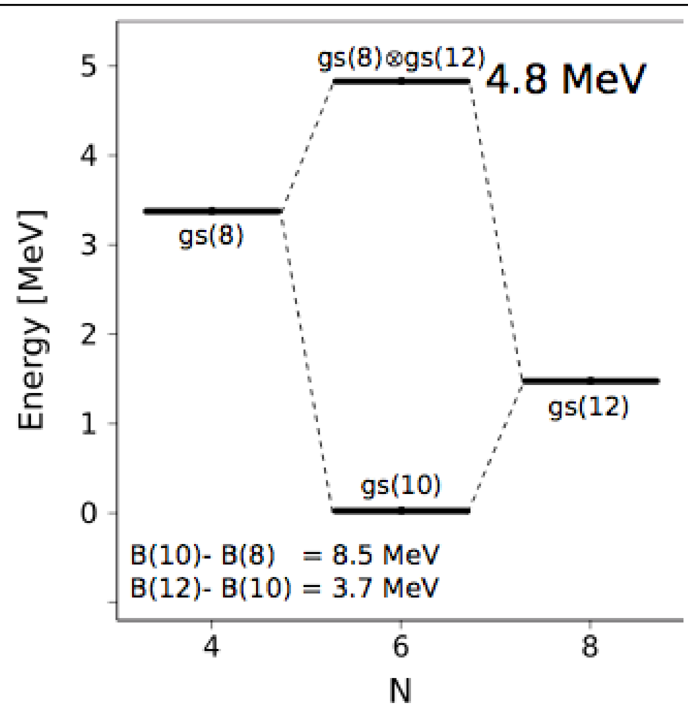

Fig.1 Pairing vibration state in ^{10}Be from ^{12}Be(p,t) reaction.

It is important to investigate if similar features are present in ^{12}Be which is the isotone neighbour of ^{11}Li but differs in being a non-borromean nucleus. It maybe expected that the 2^+ state in ^{10}Be plays an important role in understanding the pairing correlation in the ground state of ^{12}Be.

The study of pairing vibration spectrum can reflect important and interesting features on shell closures [3]. Around the sub-shell closure N=6 in neutron-rich nuclei one can expect a 2p-2h pairing vibration (0^+) state in ^{10}Be to be located around 4.8 MeV excitation energy, in a harmonic approximation from the binding energy differences of ^{8,10,12}Be. In the ^{12}Be(p,t)^{10}Be reaction this pair removal state is then expected to be excited (Fig.1). Presence of such an excited state together with its cross section compared to the ^{10}Be ground state in a two-neutron transfer from ^{12}Be will help to draw a more clear conclusion regarding the N=6 sub-shell closure.

The ground state structure of ^{12}Be shows smaller component of the $2s_{1/2}$ orbital (compared to ^{11}Be) [4.5] with a strong mixing of the $1p_{1/2}$ [4] and $1d_{5/2}$ [6] orbitals. In ^{12}Be there is much larger occupancy of the valence neutrons in the $1d_{5/2}$ orbital than in ^{11}Li whose effect on pairing correlation is interesting to investigate.

This motivates the present proposal to attempt for a pioneering measurement of ^{12}Be(*p,t*)^{10}Be reaction with the aim to detect the levels populated in ^{10}Be. The first aim of this proposal is to observe the levels of ^{10}Be residue and extract the angle integrated cross section within the detector coverage. This will be used to identify the paring vibration state and find the ratio of the cross section of such a state to the ground state of ^{12}Be. The ratio provides a measure to understand the N=6 shell closure. We will attempt to find the angular distribution if the cross section is large and sufficient statistics is collected.

In addition, the inelastic scattering of ^{12}Be from protons will be used to investigate the nature of excited state at 2.68 MeV. This state has been ascribed to have a 1^- spin from Coulomb excitation measurement, since the state populated in excitation only with a Pb target and not with a C target. The spin confirmation was also based on inelastic scattering of alpha particles. The ^{10}Be(*t,p*)^{12}Be reaction however reported a level in ^{12}Be around 2.7 MeV to be of 0^+ in nature. It would therefore be useful to have an independent confirmation from proton inelastic scattering regarding the multipolarity of this excitation. Such information can be obtained by measuring the angular distribution for the forward center of mass angles.

2. Experiment

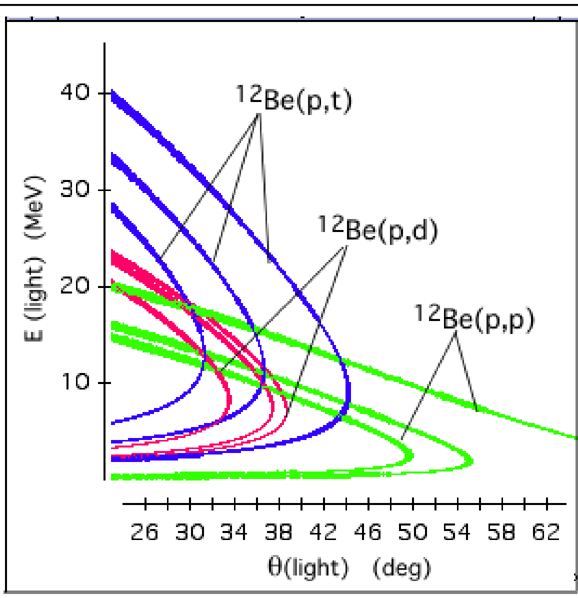

Fig.2 Kinematic loci for 12Be+p reactions showing the energy of the light target-like ejectile plotted against its laboratory scattering angle.

The ^{12}Be(p,t)^{10}Be experiment will be performed using a beam of ^{12}Be reaccelerated to ~7 MeV/u. The reaction kinematics is shown in Fig.2. The light particles will be detected using an annular array of segmented silicon and CsI detectors (Fig.3) placed ~ 11 cm after the target. The heavy residue will be detected using smaller array of silicon detectors placed ~ 45cm downstream of the target. This detector placement will allow coincident detection of the heavy residue for tritons that are stopped in the ΔE silicon detector. We also plan to stop and count the beam using a radiation hard scintillator detector.

The ΔE-E correlation of the light particles can be used to identify the reaction channel of interest as shown in Fig.3 from simulation. However, some of the low-energy tritons and deuterons will stop in the ΔE silicon detector. For these events one needs to have coincident detection of the heavy residue as well to aid in the identification.

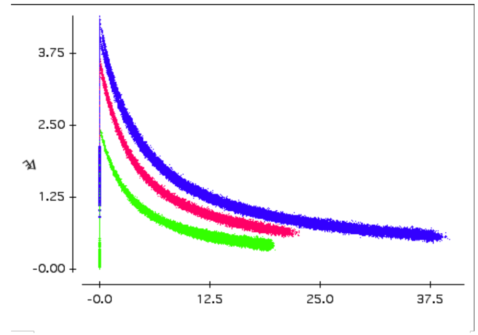

Fig.3 ΔE-E correlation of light target-like ejectile.

The heavy residue can be identified using ΔE-E correlation of the smaller silicon telescope array. Simulated events of such identification for events stopping in the light particle ΔE silicon detector is shown in Fig.4.

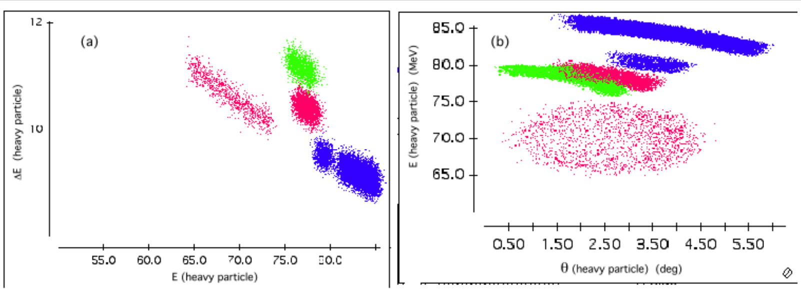

Fig.4 (a) ΔE-E correlation of the heavy projectile like residue in coincidence with events stopped in the ΔE detector of the light (target-like) ejectile. (b) Energy and angle of the heavy residue detected in the silicon detector.

The experiment will also be able to study the levels in the ^{11}Be from one-neu3ron removal as can be seen from the detector coverage of the simulated spectra, This information would be useful for a complete understand of the two-neutron transfer process (i.e. direct and sequential transfer).

We would also like to perform a separate experiment on proton elastic scattering of ^{11}Be to study the variation of nuclear interaction (optical potentials) between the loosely bound one-neutron halo ^{11}Be with neighbouring even-N isotope(s). The beam intensity of ^{11}Be available at ISAC ~ 10^5/sec of accelerated beam which would be sufficient to perform this experiment with a CD_2 target.

3. Beamtime

The beamtime requested is based on ^{12}Be yield measurement reported at ISAC, with the estimate of ~ 400/sec of accelerated beam. The differential cross section for ^{12}Be(p,t) reaction was calculated using the nuclear field theory approach (Fig.5). The integrated cross section in the angular region of θ_{cm} = 10-50° is ~ 6 mb at E/A= 7 MeV with the total cross section being 10mb integrated upto 150°. Based on this estimate using a 100um thick solid hydrogen target we expect to observe ~ 1800 counts in 10 days for the forward center of mass angle region.

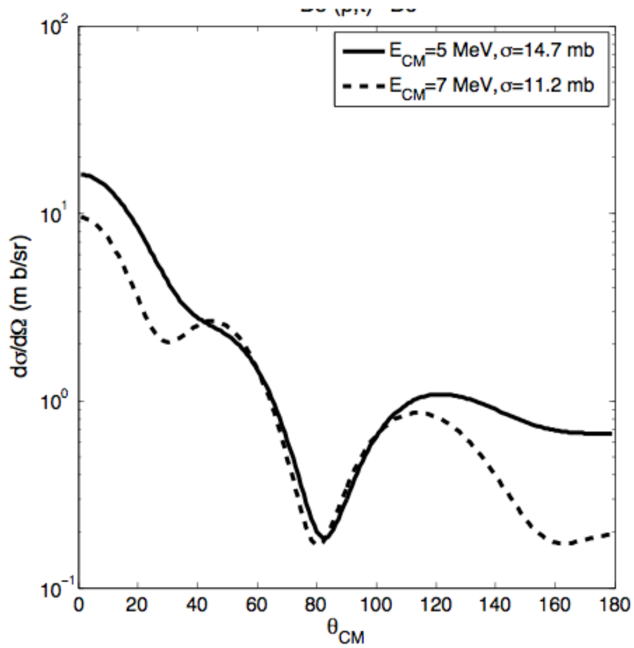

Fig.5 Calculated angular distribution for the ^{12}Be(p,t) reaction.

This data taking time estimate can accommodate a factor of ten reduced cross section which might result from as a lower limit of observing the ^{10}Be levels.

We also request a stage-2 approval for this experiment since the beam has been developed and we expect the experimental facility to be commissioned in Spring of 2012. If necessary we will keep the option of using a CD_2 target.

Table 1. : Beamtime Request Summary

Job	**Time (shifts)**
Setup of electronics, DAQ	2
^{12}Be(p,t):data taking	20
Total beamtime	22

References

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[5] R. Kanungo et al., Phys. Lett. B 682 (2010) 391.
[6] S.D. Pain et al., Phys. Rev. Lett. 96 (2006) 032502