Structure of ^{13}Be through isobaric analogue states in ^{13}B

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Structure of ^{13}Be, exotic unbound isotope that has four more neutrons than the only stable beryllium isotope ^{9}Be, has been a major puzzle over the last decade. Naive shell model considerations indicate that ^{13}Be should have a $1/2^-$ ground state because it is well known that 2s1/2 shell is the lowest in ^{11}Be, it is filled in ^{12}Be, and the next valence neutron should occupy the unfilled 1p1/2 shell in ^{13}Be. However, it is known that valence nucleons in the ground state of ^{12}Be (^{10}Be+2n) are in the mixed $1p_{1/2}$+$2s_{1/2}$ configuration [1]. Moreover, theoretical calculations and experiments done on ^{13}Be have been unable to come to agreement with some finding a ground state of $1/2^+$ and others $1/2^-$ (see references in [2]). There is a general consensus only about a resonance at around 2 MeV above the neutron decay threshold, that was first observed in the ^{14}C(^{7}Li,^{8}B) reaction [3]. After that it has been observed in many other studies and based on indirect and/or theoretical arguments the spin-parity of the 2 MeV state is believed to be $5/2^+$. The rest of the ^{13}Be spectrum is still uncertain, as there are no conclusive experimental spin-parity assignments for any of the states in ^{13}Be, including the ground state. Three more states ($1/2^+$, $1/2^-$, and $5/2^+$) have been suggested below 2 MeV in various studies but neither can be considered as conclusively established (see for example [4-7] and Refs. therein). The experiments performed to date can be divided into two major groups: the experiments that use invariant mass or sequential neutron decay spectroscopy with rare isotope beams at high energy $\sim$100 MeV/u [4-7] and the multi-nucleon transfer reactions [3]. In either case the interpretation of the results is complicated by the uncertainties in the reaction mechanism resulting in ambiguities in spin-parity assignments. On top of that, at least some of the low-lying states are expected to be broad and overlapping resonances which are populated with different probability by different reactions. As a result, it has been very challenging to come up with conclusive and self-consistent interpretation of all of the experimental data so far.

To overcome the difficulties mentioned above, instead of studying ^{13}Be directly, we have studied the T=5/2 states in ^{13}B, the isobaric analogs of ^{13}Be. These states were populated in ^{12}Be+p resonance elastic scattering and measured using the state-of-the-art active target detector TexAT. In July of 2019 we moved the Texas Active Target (TexAT) detector [8] to TRIUMF to run ^{12}Be + p experiment using the ISAC II rare isotope beams facility. A beam of ^{12}Be with an energy of 6 MeV/u was used for the experiment with a target gas of isobutane at 260 Torr. This combination of beam energy and gas pressure allowed for a measurement of the excitation function from 6 MeV down to 1 MeV. This energy region is where the ^{13}Be low laying T=5/2 states are expected to be found.

The TexAT detector uses a highly segmented a Micro-Mesh Gaseous Structure (MicroMegas) detector to track particles in the chamber. For additional amplification a Gas Electron Multiplier (GEM) was placed in front of the MicroMegas plate. Tracks of the beam, heavy recoil, and light recoil particles are recorded by the TPC. An array of CsI backed Si detectors was placed at forward scattering angles to measure the energy of the light recoil particles. The particle tracks, in conjunction with the energy measured in the Si-CsI array, are used to reconstruct the reaction kinematics.

Analysis of the data is ongoing. Particle identification has been done for events where the light recoil particle has sufficient energy to pass through the Si detector into the CsI detector (Fig. 1). There is

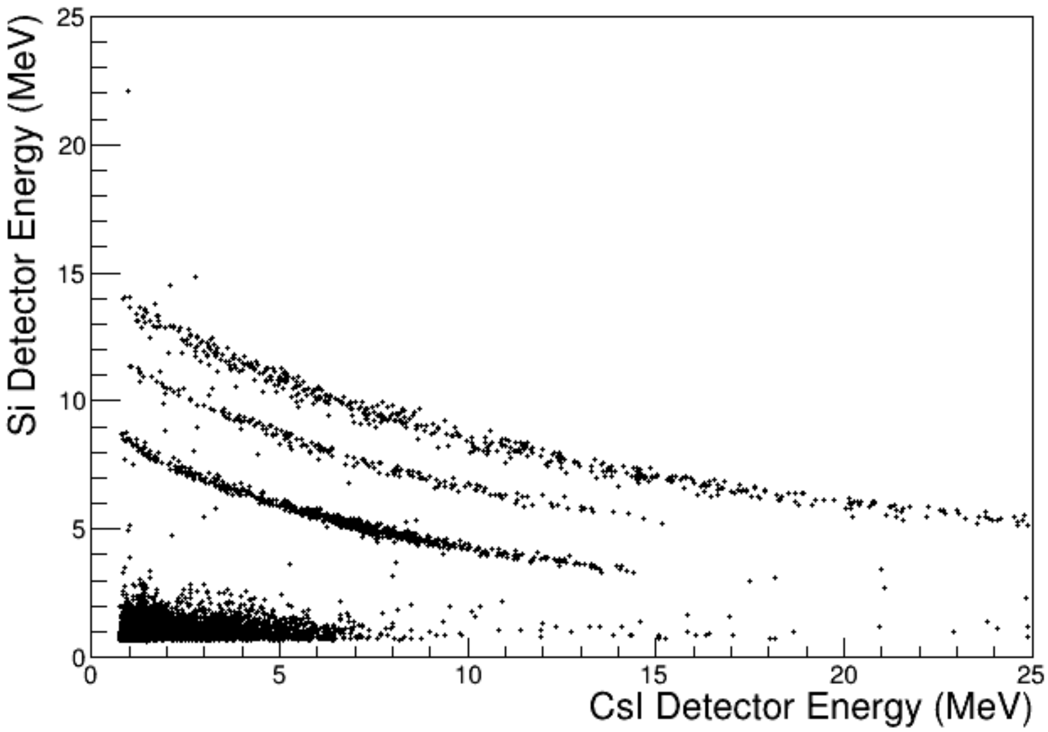

Fig. 1. Si Energy vs CsI Energy plot showing proton, deuteron and triton bands.

a clear distinction between protons, deuterons and tritons. Track reconstruction for the side regions in TexAT has been successful for the majority of events giving a measure of where the reaction occurred in the chamber. Using the reaction location with the energy deposited in the detectors the events of interest can be identified (Fig. 2). This will be used to create and excitation function from the energy of the protons in the Si-CsI array. R-Matrix analysis will be used to establish the structure of T=5/2 states in ^{13}B and infer the spin-parities of the low-laying states in ^{13}Be.

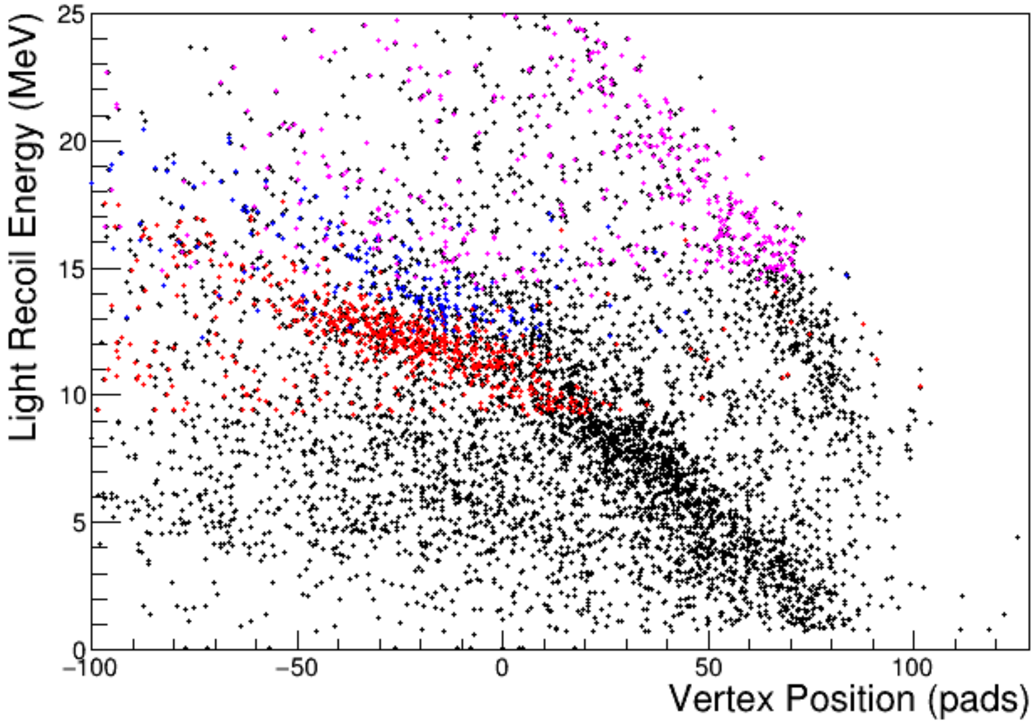

Fig. 2. Light Recoil energy plotted against the reaction position from track reconstruction. The colors correspond to protons (red), deuterons (blue), and tritons (magenta) as determined by the Si vs CsI energy plot. A strong band of protons corresponds to the 12Be + p elastic scattering reaction.

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