Studying Unstable Light Nuclei with Transfer Reactions

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Motivation

Structure information on unstable, light nuclei is still not well known. We will be using single particle transfer reactions to investigate the structure of light neutron-deficient nuclei. We will then be able to test modern nuclear theories, including ab initio nuclear models and reaction theories, by comparing them with our data.

Reaction Studies:

- d(^{8}B,p)^{9}B – at MARS/TAMU using TexAT chamber
- d(^{10}C,t)^{9}C – at MARS/TAMU using TexAT chamber
- ^{10}B(^{3}He,α)^{9}B – at FSU using Super-Enge Split-Pole Spectrograph
- d(^{7}Be,n)^{8}B – at FSU using RESONEUT

- During these studies, we will be able to learn about the structure of the ground states of radioactive beams. ^{10}C is thought to have a cluster structure and ^{8}B, along with ^{9}C, are proton "halo" candidates.

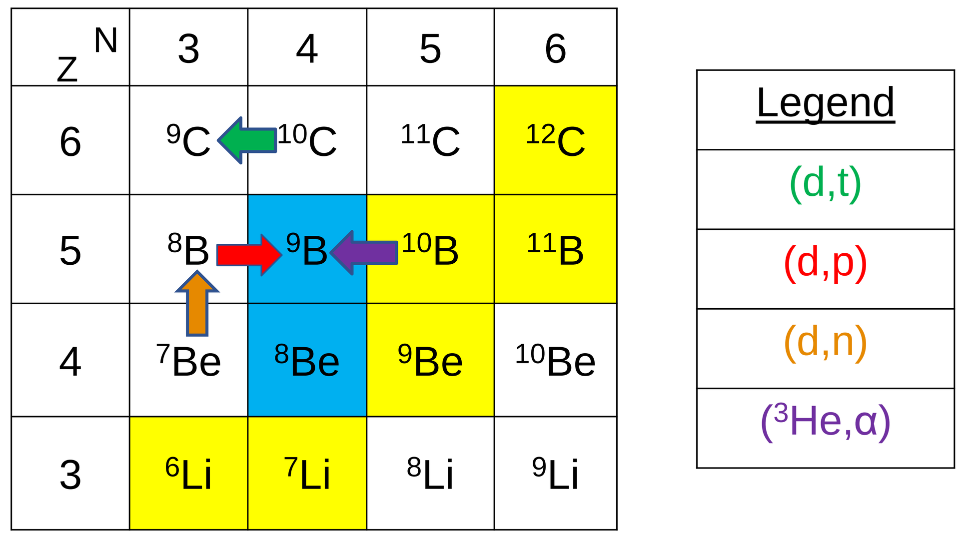

Figure 1: The direct transfer reactions we are planning on performing are shown on a section of the chart of nuclides where stable elements are colored yellow, unbound systems are colored blue and nuclei that undergo beta decay are colored white.

Measurements

- Identify excited states and their widths.
- Determine angular distributions, which we can use to make assignments of spin and parity of the final nuclear state by comparing with reaction theory calculations.
- Calculate absolute cross sections, which will be used to obtain spectroscopic factors by comparing reaction model calculations to our experimental data.

Studying the Structure of ^{9}B

- Over the years, there have been many studies to find the energy and width of the first-excited state of ^{9}B, which is the mirror of the first-excited state of ^{9}Be (J^{π}= ½$^{+}$, E_x =1.684±20 MeV, Γ=214±5 keV). However, this is a difficult state to populate and the results are varied (Table 1). By comparing the most current energy level diagrams of ^{9}B and ^{9}Be (Figure 2) we can see how much more information we have on the latter.
- We plan to explore the low-lying structure of ^{9}B using neutron adding and removing reactions: ^{10}B(^{3}He,α) and d(^{8}B,p).

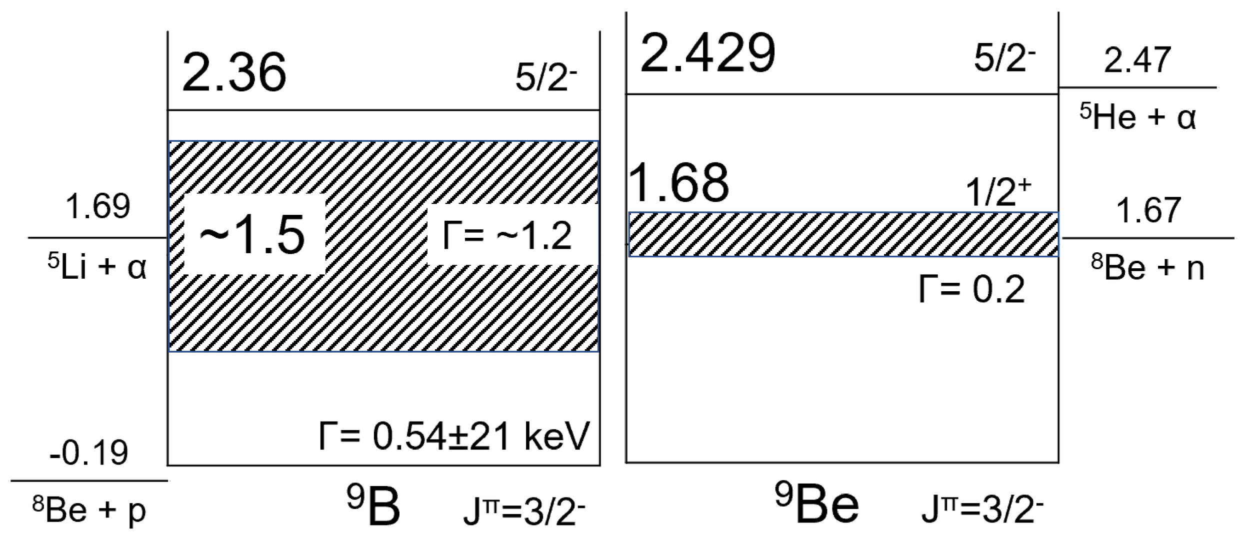

Figure 2: Comparing the energy level diagrams of ^{9}B and its mirror nucleus ^{9}Be. Energies and widths are in MeV, unless otherwise denoted, and are from the TUNL and NNDC Database.

Year	Author	E (MeV)	Γ (MeV)	Reaction
1968	J. J. Kroepfl[1]	~1.6	0.7	^{10}B(^{3}He, α)
1983	A. Djaloeis[2]	1.65 ± 0.03	1 ± 0.2	^{9}Be(^{3}He,t)
1987	K. Kadija[3]	1.16 ± 0.05	1.30 ± 0.05	^{9}Be(^{3}He,t)
1988	M. Burlein[4]	1.32 ± 0.08	0.86 ± 0.26	^{9}Be(^{6}Li,^{6}He)
1988	N. Arena[5]	1.8 ± 0.2	0.9 ± 0.3	^{10}B(^{3}He, α)
1995	T. D. Tiede[6]	0.73 ± 0.05	0.3 ± 0.05	^{6}Li(^{6}Li,t)
2012	M. A. Baldwin[7]	0.9 ± 0.1	~1.5	^{6}Li(^{6}Li,d)^{10}B*
2015	C. Wheldon[8]	1.85 ± 0.06	0.65 ± 0.125	^{9}B(^{3}He,t)^{9}B

Table 1: A non-comprehensive summary of measurements of the first-excited state of ^{9}B including the year of publication, its primary author, the reaction used and the resulting energy and width with uncertainties.

Experiments at TAMU

- The d(^{8}B,p)^{9}B study will be performed using the Momentum Achromat Recoil Spectrometer (MARS) (Figure 3) because it is capable of producing a ^{8}B beam at higher energies (15-25 MeV/A) and intensities (>10^{4} ions/s).
- We will expand on the current Texas Active Target (TexAT) chamber to house detectors able to detect and identify light ion decay products (Figure 4).
- The d(^{10}C,t)^{9}C study will use a similar layout at this facility.

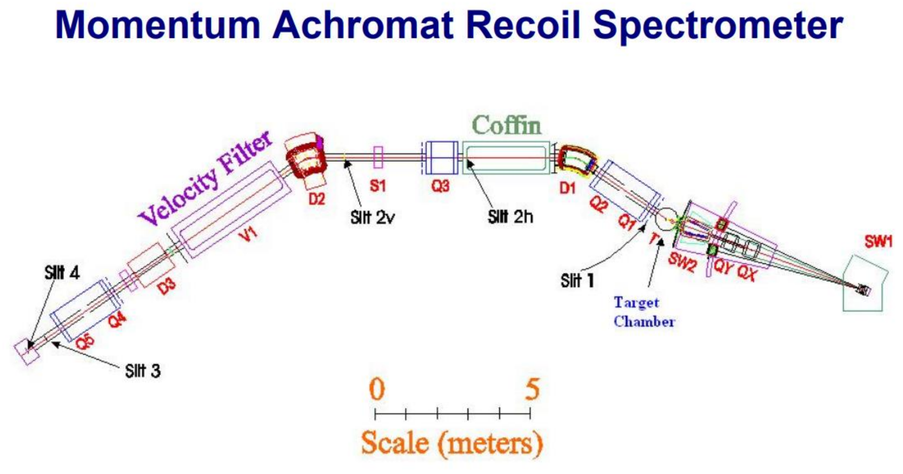

Figure 3: Layout of the MARS facility at Texas A&M.

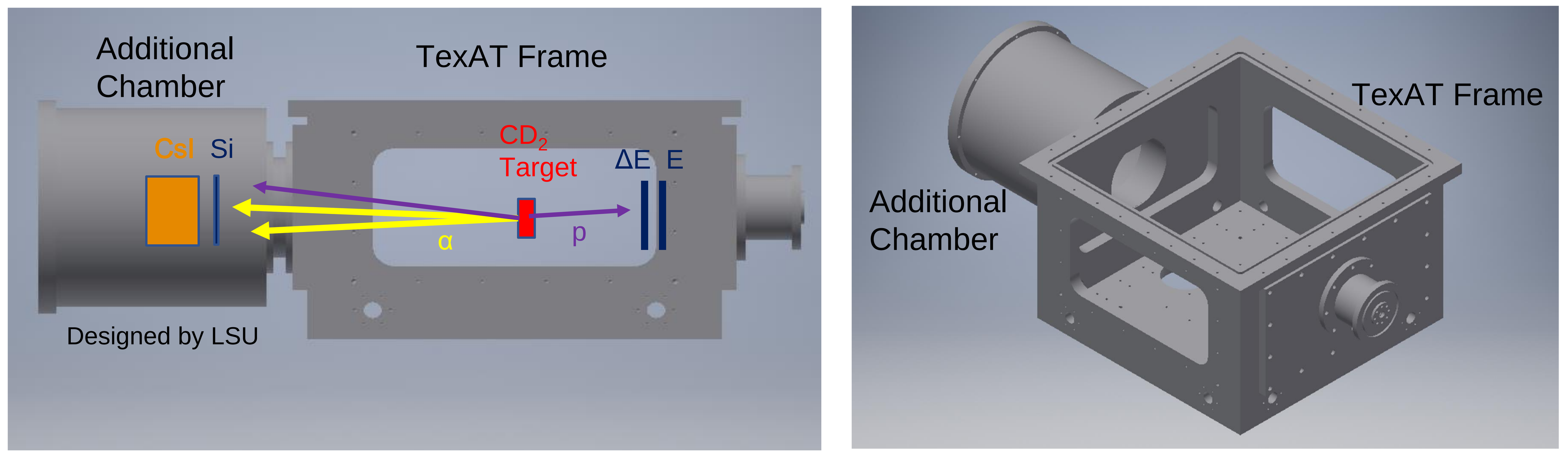

Figure 4: Both of the above images show the proposed chamber design while the one on the left depicts the specifics of our detector layout.

Experiments at FSU

- The ^{10}B(^{3}He,α)^{9}B study will be investigated using the new Super-Enge Split Pole Spectrograph (SE-SPS), circled in red on Figure 5 of the FSU facility. A closer look at SE-SPS is shown in Figure 6.
- The d(^{7}Be,n)^{8}B study will be developed using existing neutron detector systems (i.e. RESONEUT).

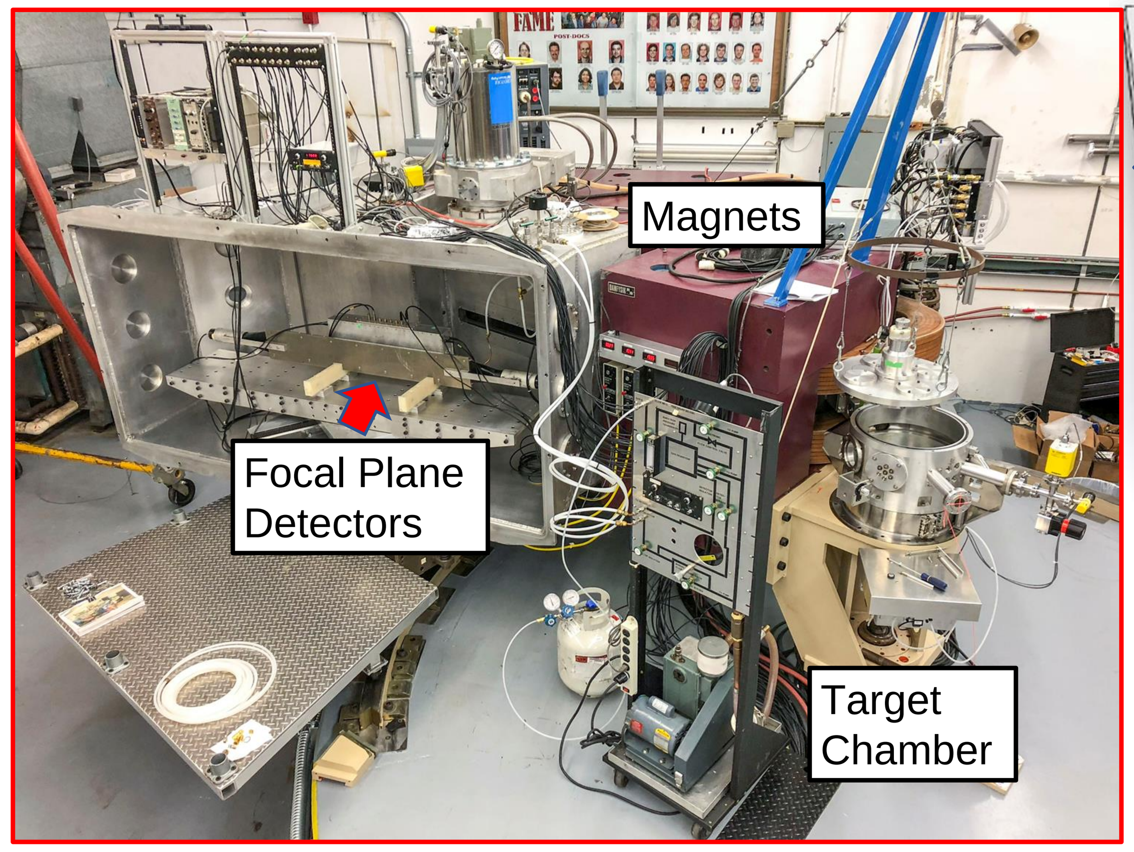

Figure 6: Photo of SPS at FSU with key components labeled.

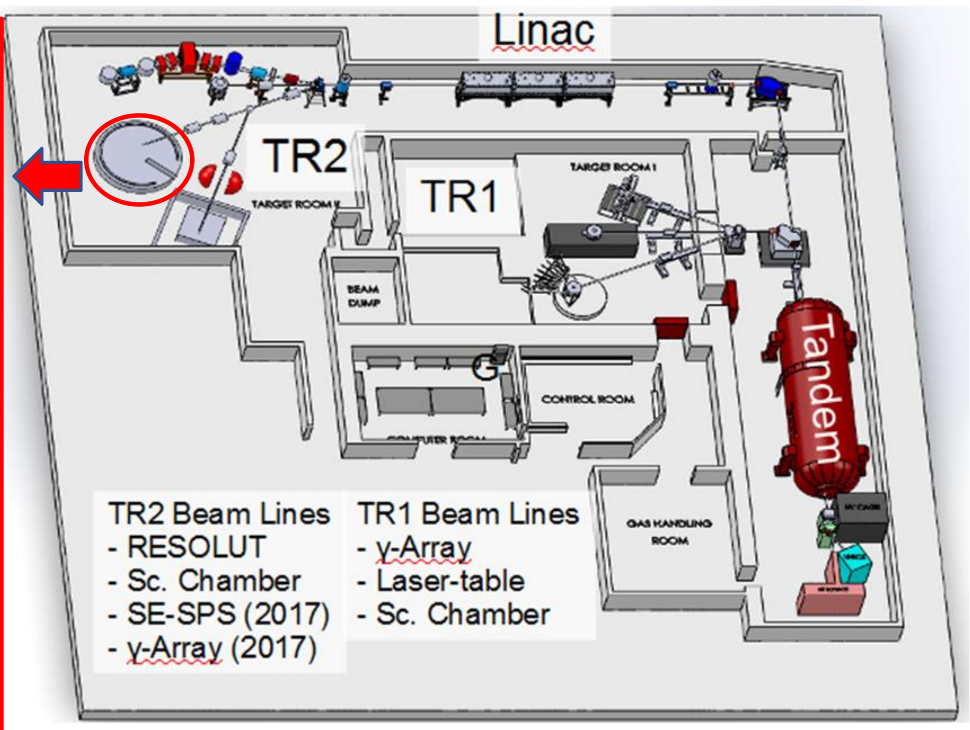

Figure 5: Layout of the John D. Fox Accelerator Laboratory at Florida State University.

References

[1] J. J. Kroepfl and C. P. Browne, Nucl. Phys. A **108**, 289 (1968).
[2] A. Djaloeis, J. Bojowald, G. Paic, and B. Antolkovic, Proc. Int. Conf. on Nuclear Physics, Florence, Vol. **1**, p. 235 (1983).
[3] K. Kadija, G. Paic, B. Antolkovic, A. Djaloeis, and J. Bojowald, Phys. Rev. C **36**, 1269 (1987).
[4] M. Burlein, et al., Phys. Rev. C **38** (1988) 2078.
[5] N. Arena, Seb. Cavallaro, G. Fazio, G. Giardina, A. Italiano, and F. Mezzanares, Europhys. Lett. 5, 517 (1988).
[6] M. A. Tiede, et al., Phys. Rev. C **52** (1995) 1315.
[7] T. D. Baldwin, et al., Phys. Rev. C **86** (2012) 034330.
[8] C. Wheldon, T. Kokalova, and M. Freer, Phys. Rev. C **91**, (2015).

Acknowledgements

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NNSA National Nuclear Security Administration