The study of alpha conjugate reactions in FAUST

B.M. Harvey, A. Hannaman, K. Hagel, A.B. McIntosh, and S.J. Yennello

Theoretical research from the past 60 years has provided extensive backing behind the potential of exotic nuclear configurations like toroidal [1], linear chains, and bubble under high angular momentum and energy conditions. The existence (or nonexistence) of these kinds of exotic nuclear structure would push our understanding of the limits of nuclear stability and our understanding of the theory that predicts them. Further, investigations of decay pathways of alpha-conjugate nuclear states, especially near threshold states have astrophysical implications [2].

To study these topics, a series of experiments were conducted at the Texas A&M Cyclotron Institute with the Forward Array Using Silicon Technology (FAUST). FAUST is a multi-detector array comprised of 68 Si and CsI telescopes. Measuring the energy deposited in the Si and CsI detectors gives particle energy and identification information. The Si detectors are Dual Axis Duo Lateral detectors, which have resistive surfaces granting them position sensitivity, and signals are read off of both the fronts and the backs, allowing for the position sensitivity to extend in both directions. The angular resolution of alpha particles is ~1-2 degrees.

The data collected for the studies of alpha-conjugate nuclei and their breakup are summarized in Table I. All experiments were <alpha-conjugate-beam> + natural carbon at 35 MeV/nucleon. The calibrations (including particle identification) are still underway, but a preliminary event count with at least one alpha particle identified is listed.

Table I. Alpha-conjugate reactions studied at the indicated dates and statistics acquired.

System	Date	# Events w/ alpha
^{16}O + C @ 35 MeV/u	Oct 2022	82 M
^{20}Ne + C @ 35 MeV/u	Jun 2022	276 M
^{24}Mg + C @ 35 MeV/u	Aug 2022	126 M
^{28}Si + C @ 35 MeV/u	Jun 2021	275 M
^{32}S + C @ 35 MeV/u	Aug 2022	266 M
^{36}Ar + C @ 35 MeV/u	Oct 2022	721 M

While most of the data is still being finely calibrated, the preliminary calibrations show promise for high resolution measurements of multiparticle excitation energy reconstruction with alpha particle reconstructions. Fig. 1 shows the quality of the particle identification achievable across FAUST, which also highlights the energy resolution that can be achieved with FAUST. One can see isotopic resolution through Z=14.

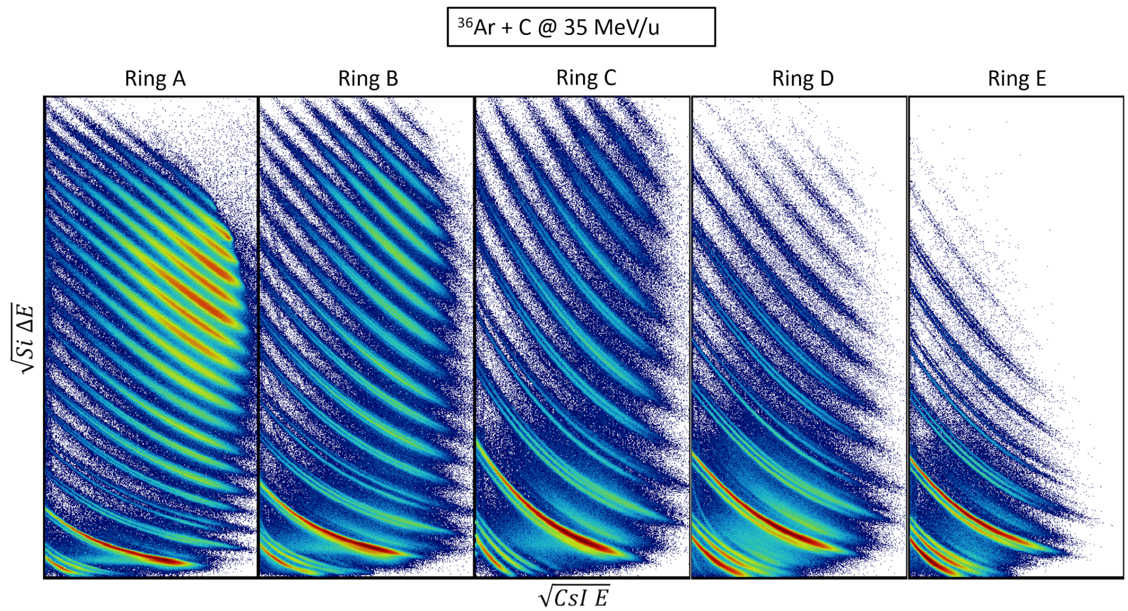

Fig. 1. ΔE vs E maps indicating particle id for the various FAUST rings

Many-particle measurements can be used to reconstruct excitation energy by assuming the particles are from the same source. Fig.2 shows 2 and 3 alpha E* distributions which give high resolution measurements of many carbon and beryllium states. The resolution of FAUST allows for a measured 55 keV FWHM of the Be-8 ground state, even with crude first order calibrations. The shown resolution is an upper limit of the resolutions achievable by FAUST.

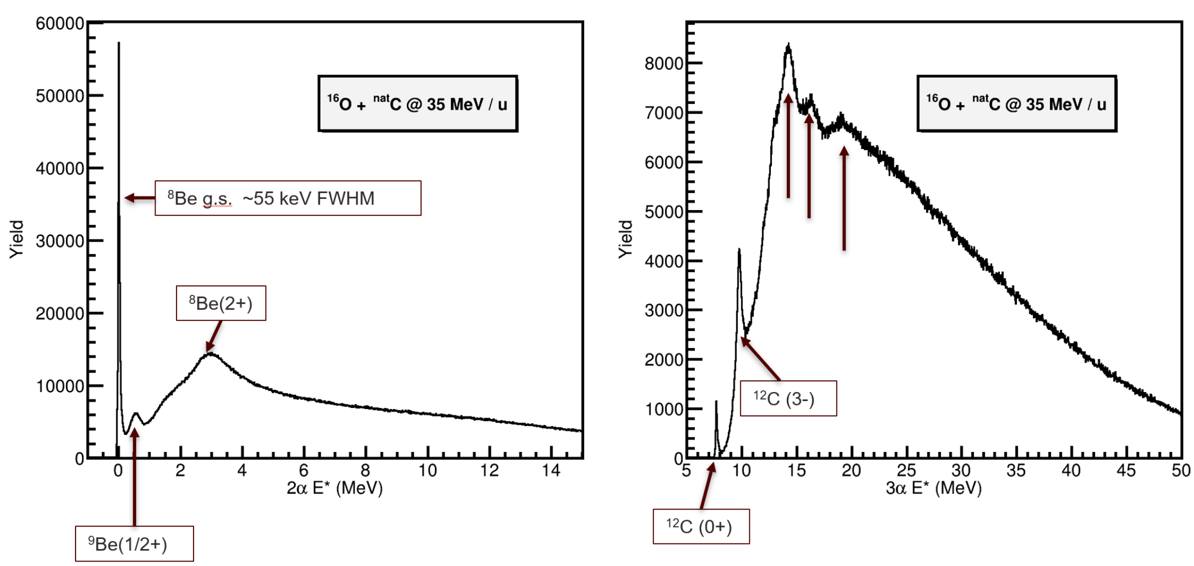

Fig. 2. Two-alpha (left) and 3α excitation energy distributions showing the various observed states.

[1] X.G. Cao, E.J. Kim, K. Schmidt, K. Hagel, M. Barbui, J. Gauthier, S. Wuenschel, G. Giuliani, M.R.D. Rodriguez, S. Kowalski, H. Zheng, M. Huang, A. Bonasera, R. Wada, N. Blando, G.Q. Zhang, C.Y. Wong, A. Staszczak, Z.X. Ren, Y.K. Wang, S.Q. Zhang, J. Meng, and J.B. Natowitz, Phys. Rev. C **99**, 014606 (2019). https://doi.org/10.1103/PhysRevC.99.014606

[2] https://www.sciencedirect.com/science/article/pii/S2095927323002852?via%3Dihub#f0015(accessed 5.12.23).