Measuring charged particle reaction products from ^{28}Si + ^{12}C at 35 MeV/u using FAUST

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FAUST (Forward Array Undertaking Search for Toroids) is a charged particle multi-detector array consisting of 68 Si-CsI(Tl) detector telescopes covering an angular range of 1.6° – 45°. The silicon detectors are position-sensitive (DADLs), measuring the position of incident particles through resistive charge splitting [1-4]. Due to distortions in the calculated energy and position of incident particles when using conventional electronics, detailed waveform analysis was performed, and a waveform treatment was developed to greatly minimize these distortions [5]. Additionally, multievent readout of the Struck SIS-3316 waveform digitizers used for DADL readout and the Mesytec MADC-32s used for CsI(Tl) readout was implemented to maximize the data collection rate of FAUST. With these improvements, reaction products from collisions of 35 MeV/u ^{28}Si on ^{12}C were recently measured, obtaining 150 million events containing charged particle detection. This work aims to search for further evidence of high-excitation toroidal states in the α(^{4}He)-disassembly of ^{28}Si, and to gain insight to the α-clustered structure and properties of α-conjugate nuclei [6].

Particle identification in FAUST is performed using the ΔE (DADL Si) – E (CsI(Tl)) technique that takes advantage of particle charge, mass, and energy dependence of ion energy loss through matter. The discrete bands seen in Fig. 1(a) show elemental separation, with the finer structure separating isotopes. The resolution of the DADL passage detectors and CsI(Tl) stopping detectors of FAUST allowed for isotopic resolution up through the beam species (^{28}Si). Isotopic yields for all measured particles in the present dataset are shown in Fig. 1(b). The position sensitivity of the DADL detectors afford excellent angular information for each detected particle. The angle of detected particles can be projected to give a depiction similar to viewing FAUST from the target position as shown in Fig. 1(c).

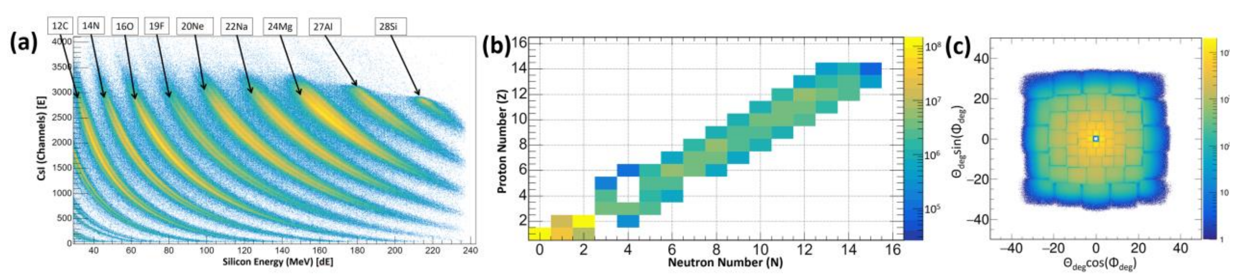

Fig. 1. (a) Representative FAUST ΔE (DADL Si) – E (CsI(Tl)) spectrum showing isotopic resolution of reaction products up through ^{28}Si. (b) Total yield as a function of isotope proton number and neutron number measured in the present dataset. (c) A projection of detection angle for all particles in FAUST.

The parallel and transverse velocities of particles with the same proton number (Z) is shown in Fig 2. The low velocity cutoff for particles up to Z = 8 is due to the threshold velocity required to punch through the DADL detector and implant in the CsI(Tl) for particle identification. For Z ≥ 9, the low velocity cutoff is due to large energy deposits in the DADL saturating the preamplifiers. The ray-like features for Z = 1 is due to the increasing difficulty of triggering on high energy light particles incident near the edge of the DADL, as the charge splitting gives small signals on the far side of the DADL that can be below threshold.

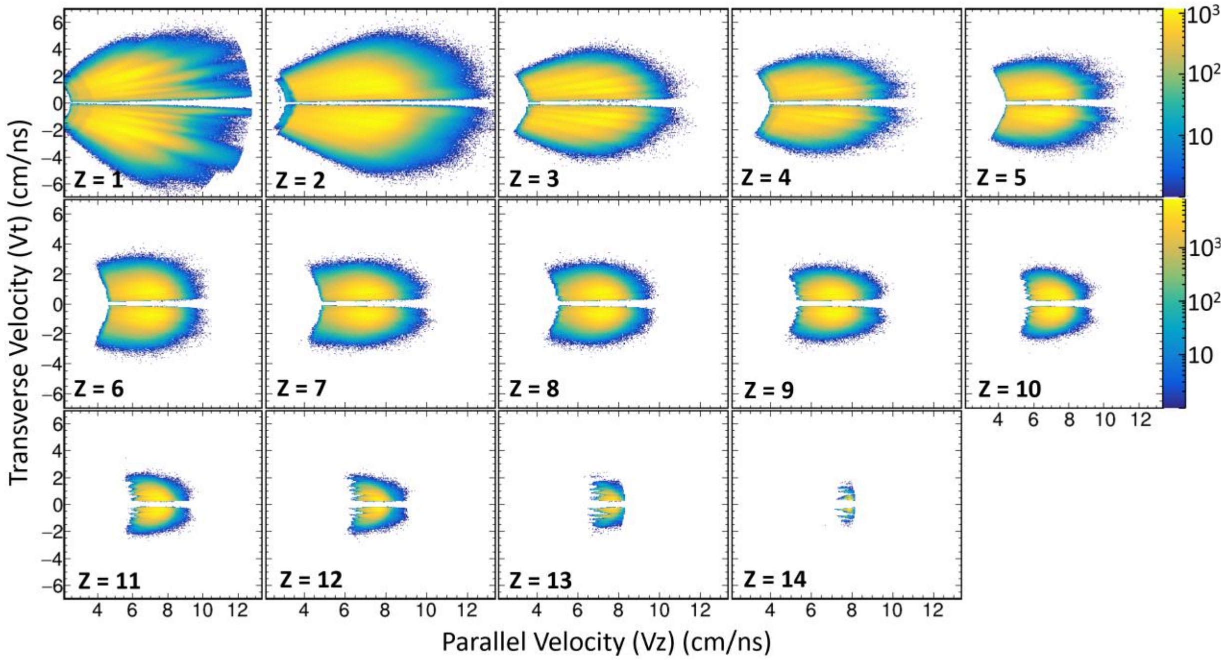

Fig. 3. Component of velocity transverse to beam axis as a function of the parallel component of velocity along beam axis in cm/ns for all particles measured in the dataset. Each panel contains particles with the same proton number.

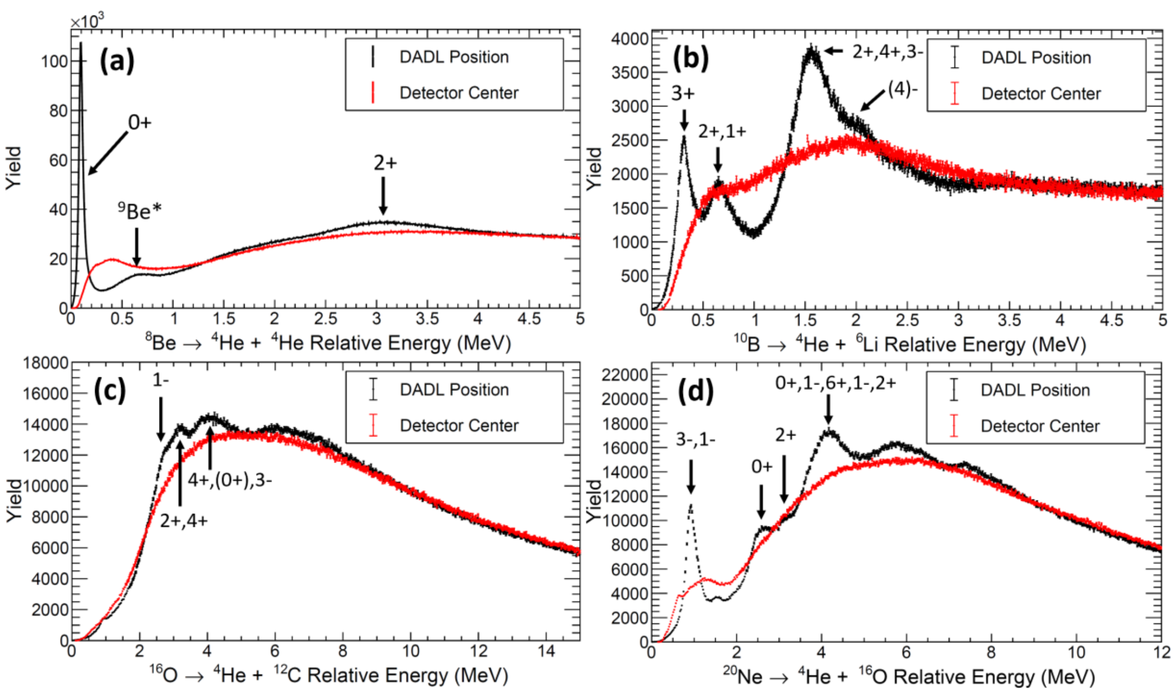

Fig. 2. Two-particle relative energy spectra for events containing at least one α-particle and a complementary particle to look for states associated with the α-emission of various N=Z nuclei. Each panel shows the distribution obtained when using the measured DADL detector position (black) and assuming the particle hit the center of the detector (red). Spin and parity of known states are assigned to some observed peaks. (a - d) α – (α, ^{6}Li, ^{12}C, ^{16}O) relative energy in MeV probing states in ^{8}Be, ^{10}B, ^{16}O, ^{20}Ne respectfully.

To resolve excited states of nuclei that undergo charged particle decay, as well as observe possible α-cluster resonances, precise angular information between measured particles is important. The position sensitivity of FAUST is crucial for this study as evidenced by Fig. 3, where multiple states are observed for these selected decay channels. Charged particles detected in arrays that use single-pad silicon detectors are typically assumed to be incident in the center of each detector, causing the angular resolution to be dictated by the angular granularity (array geometry and number of detectors). The improvement between this treatment(red) and implementing the DADL position(black) is considerable. Many states are entirely unobserved in the center-of-detector treatment due to the large systematic error in particle angle. Detailed analysis of this dataset is currently underway.

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