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ISOL-like beams of 22Al and 26P at FRIB

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The Facility for Rare Isotope Beams (FRIB) in the United States, with its superconducting radio frequency linac slated to deliver 400 kW of beam power at up to 200 MeV/u [1], is beginning —already at 1-5 kW of beam power —to open new avenues of in-flight beam production and, hence, of new experimental insights across the chart of nuclides [2].

The FRIB experiment E21010, carried out in June 2023, is the 10th scientific user experiment carried out at FRIB, and it is the first experiment to utilise the Gas Stoppers available at FRIB [3] to first thermalise the 130 MeV/u in-flight-separated beams and then to re-accelerate the beams to 30 keV. In this way, fast radioactive beams of ^{22}Al and ^{26}P, which can currently only feasibly be produced at in-flight facilities, are slowed down to low-energy beams of ISOL quality. In the experiment, the high-quality, low-energy beams of ^{22}Al and ^{26}P are stopped in a thin catcher foil in order to study the subsequent beta decays of the beam particles; the yields of beta-decaying ^{22}Al and ^{26}P from the present experiment are at least an order of magnitude larger than previously seen in experiments which utilised implantation of fast beams in stacks of detectors [4,5].

The remarkable improvement in yield and beam quality is complemented by silicon detector telescopes of high spatial and energy resolution which cover roughly 40% of 4π around the thin catcher foil in which the beam particles are stopped. The silicon detector telescopes enable detailed studies of the β-delayed proton (βp) emission and of the β-delayed two-proton (β2p) emission from the parent nuclides.

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The distribution of individual proton energies E_i for a given energy release in two-proton emission $Q_{2\mathrm{p}}$ reveal the nature of the particle break-up —sequential vs. direct. The above figure shows the 8000 β2p events recorded from ^{26}P during the E21010 experiment at FRIB.

For both ^{22}Al and ^{26}P, previously only two β2p branches, both via the IAS, were known. Based on this recent experiment, it is possible to identify many more decay channels, and to properly separate β2p and βp events; it is possible to map the level distributions of the exotic daughter nuclides by identifying gamma transitions in coincidence with emitted protons (utilising the germanium detectors also available during the experiment); and it is even possible to make all-new, unambiguous spin and parity assignments based on hitherto unobserved cases of β-delayed α emission.

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[4] C.G. Wu et al., Phys. Rev. C 104 (2021) 044311.
[5] P.F. Liang et al., Phys. Rev. C 101 (2020) 024305.

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