Demonstration of zero-degree axial field ionization counter for measuring heavy residues for use with DAPPER

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The Detector Array for Photons, Protons, and Exotic Residues (DAPPER) has been commissioned and used to measure reactions of ^{57}Fe(d,pγ)^{58}Fe @ 7.5 MeV/u which is calibrated, analyzed to extract the photon strength function and level density; the results are in preparation for publishing.

In preparation for use of DAPPER with rare isotope beams, a zero-degree detector is needed to separate, event by event, reactions with the beam species of interest from reactions with contaminants in the beam. In the past, we have investigated PPACs, diamond detectors, and YAP scintillators with no detector passing all of our qualifications. Sufficient energy (or timing) resolution is needed to distinguish adjacent elements in the Fe/Co region even at rates of at least 300,000 particles per second.

In collaboration with S. Pain of ORNL and colleagues, we have tested a fast axial-field segmented IC with a cocktail beam of Fe and Co at 7.5 MeV/u. This is the current IC used with the GODDESS array. There are grids of thin 0.0007" wires of gold-plated tungsten. The distances between the grids is about 0.5". Each grid has a wire spacing of 2mm, giving 99% transmission through each grid, and the wires in each grids are designed to shadow the wires in successive grids to maximize transmission. The grids alternate in potential; electrons and ion have little distance to travel before being collected. All cathode grids wires from all planes are electrically tied to provide a single signal proportional to the total energy. The first anode grid treats individual wires separately to provide position sensitivity; the second anode grid provides position sensitivity in the orthogonal direction. The subsequent seven anode grids can be tied together into up to three groups by jumpers on the preamp board to provide energy loss measurements. All signals are amplified with Zeptosystems charge sensitive amplifiers with the highest gain (nominally 15 mV/MeV), and with the feedback resistor modified to half its value to decrease the output signal fall time. The CSA output are sent to MSCF shaping amplifiers with minimal shaping time (0.25us) and low gain on the input stage amplifier (higher gain on the input stage saturates the current buffer at a lower rate and temporarily disables the buffer while baseline is restored). The short shaping time causes the amplifier to run in ballistic deficit, but the modest loss in energy resolution is tolerated in exchange for the ability to run to high rate. Pressure of just over 100 Torr isobutane was used to stop the beam comfortably before the end of the IC. The gas in the IC is static, not flowing, allowing for a constant gas mass, minimizing change in IC stopping power with temperature. The Anode 0 channel was selected to include the first four anode planes to select energy loss before the Bragg peak to maximize Fe/Co discrimination.

Fig. 1 shows the yield vs Anode 0 vs Cathode signal for moderately high rate (~70,000 pps as measured with an LED on the fast output of the shaper). The two most intense spots correspond to the Fe (lower anode amplitude) and Co (higher). These are well separated at this rate, and good separation is observed even at a measured beam rate of 600,000 pps. In fact, it is certain this rate is under-counting the actual beam rate due to pile up in the shaper pulse; this may be as bad as a factor of two or three. It is likely possible to correlate the observed change in the leakage current in the IC bias supply to determine the beam rate, though the resolution of this method is not firmly established. Other features of Fig. 1 are due to stopping in the wires (spots left and diagonal down from the main peaks) energy loss in the wires (continuum line toward lower energy) and pile-up pulses corresponding to double hits in the IC. The proportion of double hits naturally increased as a function of beam intensity.

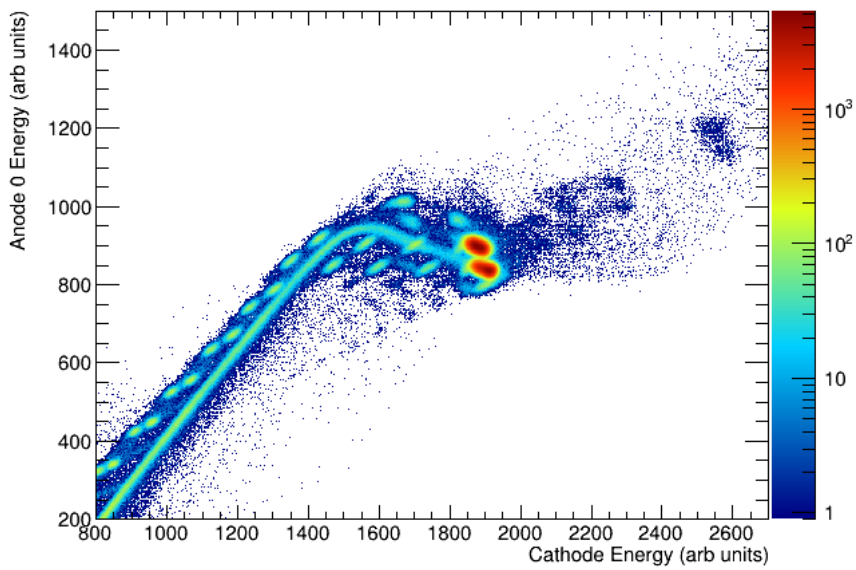

FIG. 1. Energy loss vs total energy observed for Fe/Co cocktail at a rate of 70kpps, run 186, October 2023, (102723).

Deconvolution of the pileup pulses may be possible through preservation of the waveform of the shaper pulse. Following this demonstration in October, the physics run in December included measurement of the waveforms from the IC for products from $^{54}Fe(d,p\gamma)^{55}Fe$. The pileup from particles in discrete beam bursts is clear, and work is ongoing to disentangle the pulse amplitudes.