Cyclotron effect on S3 annular silicon detector resolution

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A Micron S3 annular silicon detector is used as a part of the experimental setup being designed to measure the photon strength function for ^{60}Fe [1]. One surface of the detector is segmented into 24 rings and the other surface is segmented into 32 sectors ("pies"), providing angular resolution. From the measured proton energy and angle, the excitation energy of the ^{60}Fe nucleus, an essential quantity for determining the photon strength function, can be calculated. The resolution of our calculated excitation energy is dependent, in part, upon the energy resolution of the silicon detector, so a test was performed to investigate how the resolution was affected by interference caused by running the cyclotron. In this test we changed various settings that are present during beam production and took source data of ^{228}Th with the silicon. As a result of this run, we have determined that our excitation energy resolution is not being limited by the resolution of our detector.

The test run was performed on the end of the MARS spectrometer with a beam of ^{40}Ar at 15 MeV/u produced by the K150 cyclotron. We used a 492 um S3 annular silicon detector (wafer 2790-01) reverse biased to -70 V with a ^{228}Th source covered with a 1.4 um Mylar foil placed 2 cm away from the center of the detector. We took six 30 minute runs where certain parameters (magnet settings, RF settings, valve positions) were changed and the source spectrum was collected. The settings for each of these runs are given in Table I. The ^{228}Th spectrum was collected (Fig. 1) and energy loss corrections were done based on the Mylar foil thickness, silicon dead layer thickness, and aluminum contact thickness for each ring. The resulting spectra were fit and the resolution of the rings were obtained and plotted as a function of the ring number.

Table I. Cyclotron and beam settings for each run.

Run Number	**Settings**
16	Cyclotron RF was on. The beam line valves were closed. The MARS magnets were turned off and the velocity filter E field was on.
17	Cyclotron RF was on. The beam line valves were opened. The MARS magnets were turned off and the velocity filter E field was on.
18	Cyclotron RF was on. The beam line valves were opened. The MARS magnets were turned on and the velocity filter E field was on.
19	Cyclotron RF was on. The beam line valves were opened. The MARS magnets were turned on and the velocity filter E field was on. The ^{40}Ar beam was directed to the slits of the MARS coffin.
20	Cyclotron RF was on. The beam line valves were closed. The MARS magnets were turned on and the velocity filter E field was on.
21	Cyclotron RF was off. The beam line valves were closed. The MARS magnets were turned off and the velocity filter E field was off.

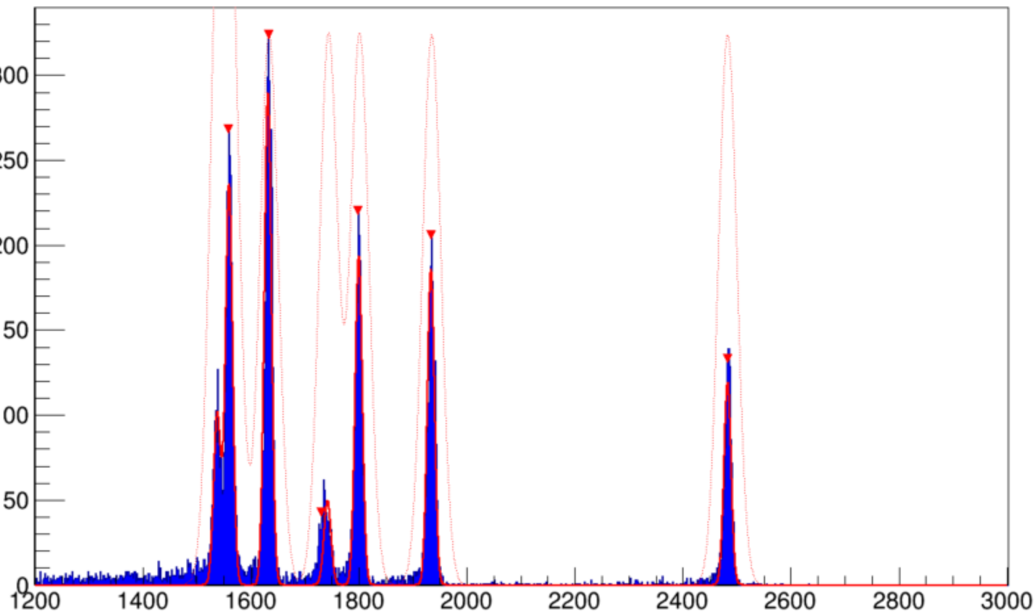

Fig. 1. ^{228}Th spectrum (blue) from ring 0, run 19. The dotted red lines indicate the initial guess fit and the solid red lines are the true fit. The red arrows are placed by the TSpectrum peak finder which give accurate guess parameters.

The resolution (FWHM) of each of the silicon rings for two particular runs are shown in Fig. 2. Runs 19 and 21 were chosen as they consisted of having either all of the settings either on or off.

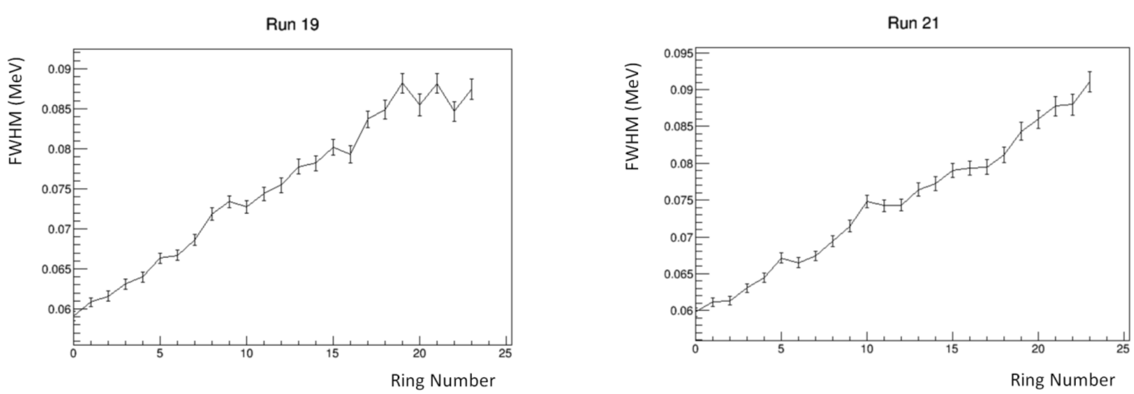

Fig. 2. The resolution of each ring is shown for two separate runs. Run 19 had all settings on and run 21 had all settings off. The resolution is relatively consistent between runs.

Although there is some variation in the resolution of the rings between the runs, they remain relatively consistent and the resolution for all rings remain below 100 keV FWHM. The increasing resolution as a function of ring number is understood to be due to the angular coverage of the rings. What is labeled as ring 0 is the innermost ring which covers the narrowest angular range while the outermost ring, labeled ring 23, covers the largest angular range which results in a reduction of the resolution. A well-collimated source would be expected to decrease this effect. Fig. 3 shows the resolution of ring 0 as a function of run number and it is apparent that there is little fluctuation in the resolution when changing different cyclotron and beamline parameters.

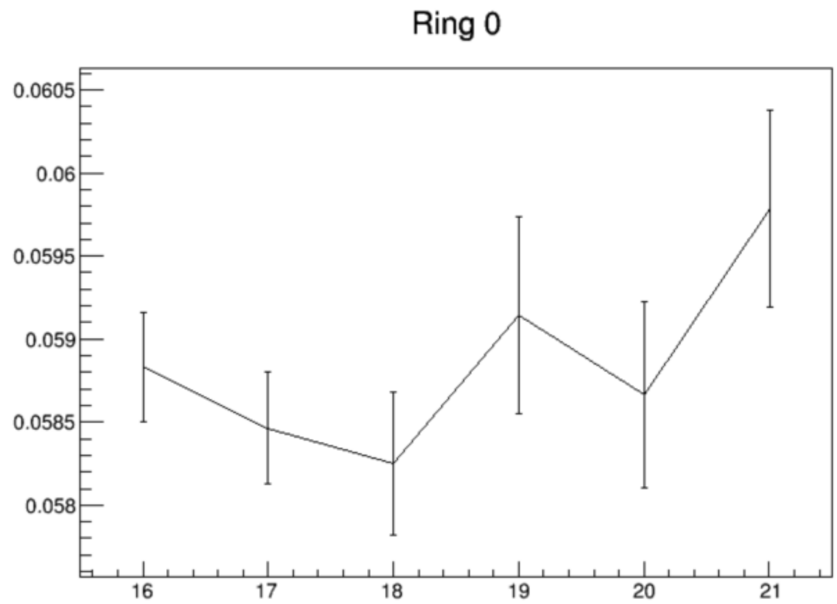

Fig. 3. Ring 0 resolution as a function of run number.

In order to see the effect of the resolution of the silicon detector on the resolution of the excitation energy of the residue, a simulation was written. This simulation takes into effect the beam spot size, silicon resolution, dead layer thickness, and target thickness. Using a worst case scenario beam spot radius of 5 mm, a dead layer thickness of 800 um, a target thickness of 0.905 mg/cm^3, and a silicon resolution of 100 keV (FWHM), the plot of the separation of the excitation energies is produced and shown below and labeled Fig. 4. With a silicon energy resolution of 100 keV (FWHM) we obtain an excitation energy resolution of approximately 600 keV (FWHM).

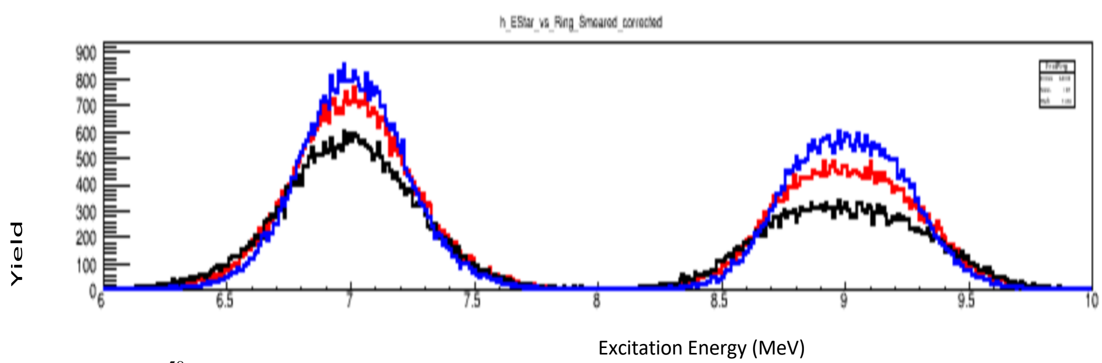

Fig. 4. Simulated ^{58}Fe residue excitation energy widths.

[1] A. Abbott *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2019-2020), p. IV-66.