Beta decay occurs when a nucleus has an excess number of neutrons compared to its more stable isobar. For example, $^{127}\text{I}$ decays to $^{128}\text{Xe}$ emitting a beta particle. The process is

$$n \rightarrow p + e^- + \bar{\nu}$$

where $\bar{\nu}$ is an antineutrino. Because there are three particles sharing the energy in the final state, the electron energy spectrum is a continuum that looks like Fig. 1.

![Fig. 1 The Spectrum of electrons emitted in the $\beta$ decay of $^{210}\text{Bi}$.](image)

This is a typical spectrum of $e^-$ energies. The energy $K_{\text{e}}^\text{max}$ is the maximum energy of the outgoing electrons.

The purpose of this experiment is to measure the half life of a beta emitter and to determine $K_{\text{e}}^\text{max}$, the maximum energy of the beta particles. In this experiment, a large NaI crystal is used both as a radioactive source and as a detector. The crystal is irradiated with a $^{252}\text{Cf}$ neutron source. $^{127}\text{I}$, which is the only stable isotope of I, captures neutrons through the process

$$^{127}\text{I} + n \rightarrow ^{128}\text{I} + \gamma$$

$^{128}\text{I}$ subsequently $\beta$ decays to $^{128}\text{Xe}$.

The emitted $\beta$ particles as well as the 440 keV $\gamma$-rays are captured in the NaI volume and are detected through the usual process of radiation detection.

To count the number of particle emitted as a function of time so that the half life can be determined, the following block diagram is used.
The amplified signal is fed to the computer which can then determine the energy spectrum of the emitted β particles. It is also fed to a unit called Single Channel Analyzer that produces a logical (i.e. a constant amplitude pulse) which is then fed to the Multi-Channel Scaling (MCS) input of the DAS. When the DAS operates in the MCS mode, it can measure a number of events per time interval independent of the energy of the event.

PROCEDURE

1. Using 1024 channels, calibrate the DAS using the appropriate gamma-ray sources. Allow at least 3 MeV as maximum energy that can be analyzed.

   Ask the instructor to irradiate the NaI detector.

   While the beta source is prepared, learn how to use the DAS in the MCS mode. Set the DAS for one pass and for 20 s dwell time.

2. After the NaI detector has been irradiated, wait 5 minutes for the decay of any short lived isotopes formed in the detector. Meanwhile, connect the detector, power it up, and place the output from the Single Channel Analyzer to the MCS input of the DAS.

3. Accumulate data for approximately 30 min. Your data in the DAS should now show the exponential decay of the radioactive source. If displayed in LOG scale, the data should be in a straight line.

4. From the equation

   \[ A_2 = A_1 e^{-t/t_1} \]

   where \( A_1 \) is the radioactivity at time \( t_1 \), and \( A_2 \) the radioactivity at a later time \( t_2 \), using two points on your graph, determine the half-life of \( ^{137} \text{Cs} \) and compare your value of the half life of \( ^{137} \text{Cs} \) to the value in the Chart of Nuclides.

   Connect the amplifier output to the ADC input of the DAS (make certain that the analyzer is set to 1024 channels) and acquire a spectrum. Compare that spectrum with the one shown in Fig. 1 and in the figures in your textbook. Calculate the energy \( K_{\text{max}} \) and compare it with the accepted value.