Calibration of Low-Energy Particle-Identification Telescopes

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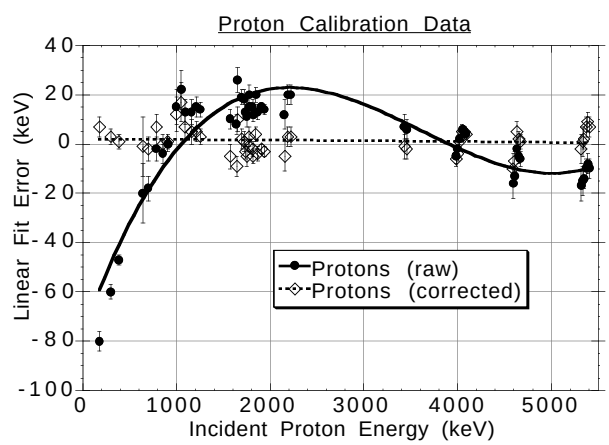
In 1993, this group began making proton spectroscopy measurements with a unique detector array incorporating six low-energy particle identification telescopes[1]. These telescopes represent the culmination of a series of designs intended to lower the proton energy threshold from ~700 keV using traditional telescopes to ~200 keV, allowing a wide range of novel measurements to be made. The traditional Si ΔE detector has been replaced in this design by two gas-ionization ΔE detectors. The gas is confined by a thin polypropylene window; the electric field is created collinear with the incident radiation between a central grid held at a high positive voltage and two outer signal-grids floating near ground.

Over the following two years, much effort went into understanding the response of these telescopes to protons and alpha particles in a high beta radiation environment. One of the first experiments performed using this array was a measurement of the beta-delayed proton decay of ^{23}Al through its isobaric analog state (IAS) in ^{23}Mg [2]. Because this state is unbound to proton emission by only 220 keV (c.m.), calibration of the decay spectrum at low energies required the development of a reliable method of extrapolation from higher-energy calibration points down to the low-energy threshold of the detectors.

Since there are no standard calibration sources of decay protons, proton calibrations are generally accomplished *in situ* using beta-delayed protons emitted from ^{25}Si produced via the ^{3}He + ^{24}Mg reaction at 40 MeV [3]. Unfortunately, the lowest energy proton group emitted by ^{25}Si has a laboratory energy of 386.1 keV; other than ^{23}Al, no emitter of lower energy protons is known. A linear extrapolation of the calibration of the Si E detector from the higher energy points would not be accurate due to two factors which increasingly cause the calibration to deviate from linearity at low energies. First, the stopping power of the detector materials increases with decreasing proton energy. Because of this, as the threshold is approached an ever-greater proportion of the incident energy is lost in the non-active components of the telescope (the window, part of the gas and the Si E dead layer). Secondly, there is a slight non-linearity between the input and output of the slow-signal electronics that is most severe near the detection threshold.

To calibrate the detector telescopes before each experiment, we make ^{25}Si as described above. We calculate the energy which will be lost by its decay protons in the window, gas and Si deadlayer using the stopping powers given in ref. 4; these are subtracted from the incident energy to determine the energy which will be detected in the Si E detector. We measure the non-linearity of the detector electronics with a precision pulser; observed channel numbers are then corrected for this non-linearity. A linear fit is made of calculated energy detected in the E detector to corrected channel. If new proton groups are observed during the primary experiment, the energy detected in the Si E is calculated from this fit, then the energy loss calculation is reversed to find the incident energy of the new groups.

To test the reliability of this procedure, two experiments were performed in which a series of thin Al foils were used to degrade protons from ^{25}Si (and alpha particles from ^{20}Na) to energies below the threshold for detection. The figure below shows a linear fit of energy to channel before and after correction for the electronics and energy losses. Using this method, it was determined that the low-energy threshold is ~180 keV for detecting protons and is ~450 keV for detecting alpha particles.



1. D. Moltz *et al.*, Nuc. Instr. Meth **A349** (1994) 210.
2. R. J. Tighe *et al.*, Phys. Rev. **C52** (1995) R2298.
3. J. D. Robertson *et al.*, Phys. Rev. **C42** (1990) 1922.
4. M. J. Berger, ed., Stopping Powers and Ranges for Protons and Alpha Particles (ICRU Report 49, 1993).