Calibrations of LCP data from recent FAUST campaign - 2015 annual report

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Data has been recorded for Light Charged Particles (LCP) from reactions of 40A MeV $^{40}Ar+^{58}Fe,^{70}Zn$, and $^{40}Ca+^{58}Ni$ at the Texas A&M Cyclotron Institute, with the upgraded Forward Array Using Silicon Technology (FAUST) detectors and electronics.

FAUST is comprised of sixty-eight ΔE-E telescopes arranged to provide coverage of particles emitted from quasiprojectiles (QP, the excited source resulting from heavy ion reactions) [1]. Each telescope consists of a 2x2 cm 300 μm thick position-sensitive Dual-Axis Dual-Lateral (DADL) silicon diode backed by a CsI(Tl)-photodiode detector [2]. The status of current calibrations of data from the successful campaign with this position-sensitive upgrade is described here. These calibrations include energy calibrations for the Si and CsI. These CsI calibrations are themselves dependent upon successful particle identification (PID) calibration.

In energy calibrations of the silicon detectors in FAUST with a ^{228}Th source, the five dominant alpha energies of ^{228}Th and its daughters result in the raw summed Front spectrum shown in Fig. 1a. The width of these Gaussian peaks at each energy is increased by some position-dependence with location of the α, due to incomplete charge collection. In order to investigate the position dependence, the sum vs. the difference of the two either front or back signals is a raw way of plotting the energy of the alpha particle against the one-dimensional (1D) position of the hit on the detector. These plots should be linear and horizontal, as the energies deposited by the single energy alpha particles should not be dependent upon the position of the incident radiation. The resultant two-dimensional (2D) histogram from the Front signals is shown in Fig. 1b. This histogram is clearly curved, rather than flat as would be expected from a purely uniform detector, indicating that the response of the DADL detectors is not completely linear as a function of position on the detector face.

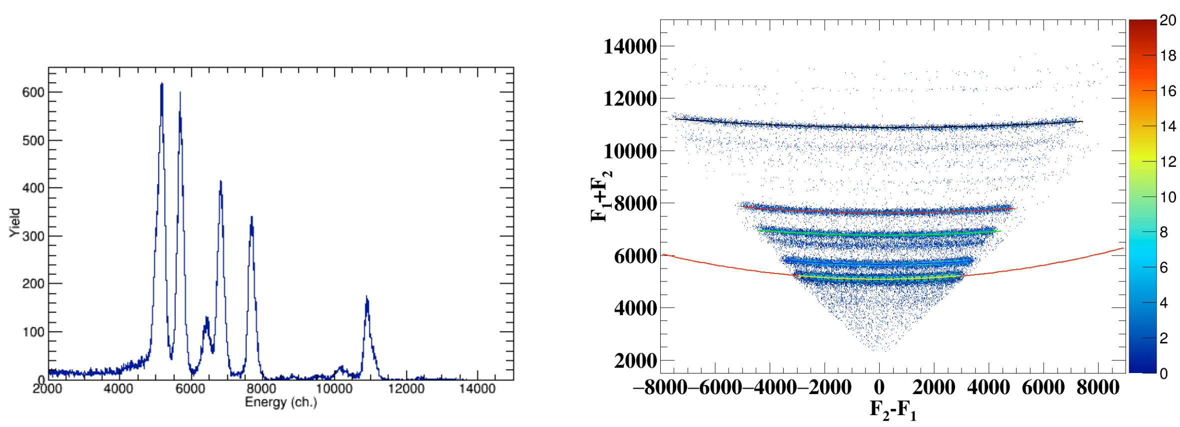

FIG. 1. (a) Energy spectrum of the alpha particles emitted by the ^{228}Th on detector 11. The raw Full-Width at Half Maximum (FWHM) is 300 keV for the highest energy α. (b) Sum vs. difference for ^{228}Th source on detector 11. These lines are somewhat parabolic in shape, and asymmetric about zero. Each line is fit quadratically.

A position-dependent correction improves the resolution of the raw energies before they can be fully calibrated. The correction necessary can be ascertained by a quadratic fit of the signals from alpha particles of different energies. Each of the lines corresponding to an energy of alpha particles from the ^{228}Th source were fit quadratically. So "a" represents the curvature of the line, "b" corresponds to the linear component, and "c" tells the y-intercept. Where x=0, the alpha particle hit the middle of the detector, and the measured values at x=0 are used as a reference to which the values at other locations are mapped. The results of this fit are also depicted in Fig. 1b.

Our aim here is to remove any position dependence of the energy. The curvature and linearity of the fits vary with the energy of the α particles. In this case, the "c" parameter of the fit is where the single-energy alpha line crosses the center of the detector, so it is some measure of the energy of the alpha particle. The non-linear components of this fit can be subtracted from the overall energy, to give a corrected spectrum and improve the energy resolution.

Because curvature and linearity are dependent upon the sum, or the c value, a and b can be replaced with linear functions that describe this relationship. Once these substitutions are made, the resultant equation for the corrected energy of any two Front or Back signals looks like this:

$$\mathrm{Sum}_{\mathrm{corr}} = \mathrm{sum} - a(\mathrm{sum})\mathrm{diff}^2 - b(\mathrm{sum})\mathrm{diff}.$$

The 2D histogram with the straightened, horizontal lines after the correction is made is shown in Figure 2b. Once the position-dependence is accounted for, the peaks from the different energy alpha particles have much better resolution. The resulting position-corrected spectrum is shown in Figure 2a. Even a merely cursory comparison between Figures 1a and 2a, the spectrum before and after, shows that the resolution of the detector is much improved by these fits and the resultant correction. This process has been implemented on all detectors for a single source run. The measured known peaks of the alphas in the thorium source spectrum have been used to convert the position-corrected raw values into MeV.

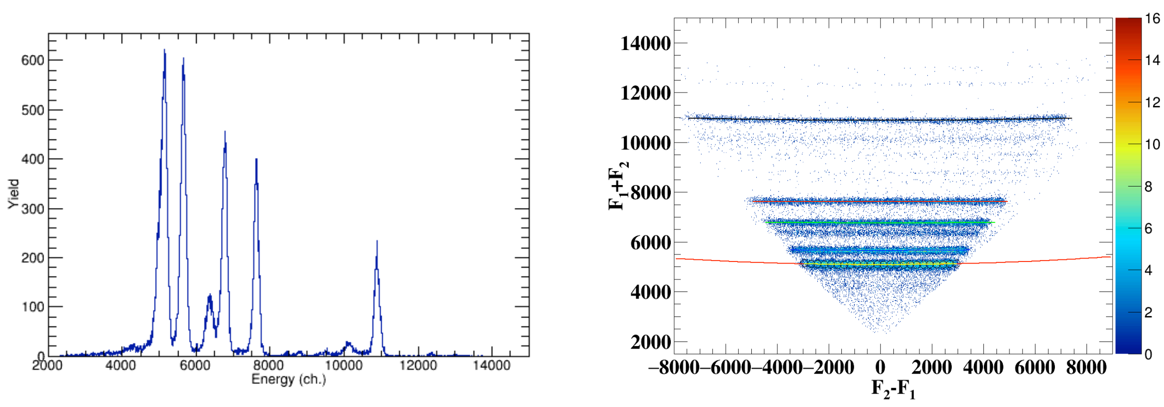

FIG. 2. (a) Corrected energy spectrum of the alpha particles emitted by the ^{228}Th source on detector 11. The FWHM is now 180 keV for the highest energy α, a significant improvement. (b) The sum vs. difference plot fit again after correction for position-dependence of energy. The highest energy alpha fit is black, followed, in order of decreasing energy, by red, green, blue, and yellow lines of fit.

The CsI energy calibration is dependent upon the PID. The ΔE-E plot, derived from Si and CsI(Tl) signals, demonstrating the excellent p-d-t differentiation for raw signals, is shown in Fig. 3a.

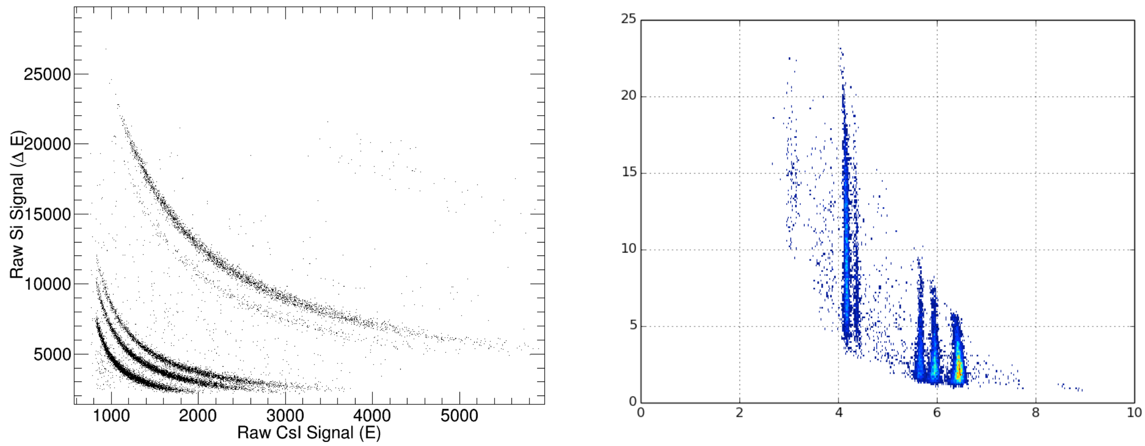

FIG. 3. (a) Representative ΔE-E plot, detector 60 for the reaction of 40A MeV ^{40}Ar + ^{58}Fe. (b) Back ΔE vs. PID value, demonstrating the linearization achievable via PID equation in text.

The PID values can be extracted using the following equation:

$$PID = b * \ln(p_0) - \ln(b * \Delta E) - (b-1)\ln(E+p_1+ \Delta E)$$

where b is defined as:

$$b = p_2 - (p_3\Delta E/p_4)$$

and slopes and intercepts for the energy calibration of Si (ΔE) and CsI (E) are allowed to be free parameters. All the parameters (p_0, p_1, p_2, p_3, p_4, b and the slopes and intercepts of the Si and CsI calibrations) are varied by hand while viewing PID vs Si or PID vs CsI as shown in Fig. 3b. The parameters result in the distribution of the PID vs Si or PID vs CsI being vertical bands when the free parameters are finalized. These free parameters are each unique to a detector, but are not observed to vary within a single system.

The subsequent linearity, demonstrated in Fig. 3b, is then good for determining the identity of particles before calibrating the CsI energy. Based on previous successful test runs and preliminary analysis, excellent PID and energy resolution are expected to be achieved in the final calibration.

Energy and position calibrations of this data set are ongoing, from which proton-proton correlation functions will be extracted. The data will then be compared to simulation results for the purpose of investigating the impact of the asymmetry energy term of the equation of state on the shape and magnitude of the correlation function, which is predicted to be significant [3].

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[2] S.N. Soisson, *et al.*, Nucl. Instrum. Methods Phys. Res. **A613**, 240 (2010).

[3] L.W. Chen, V. Greco, C.M. Ko, and B.A. Li, Phys. Rev. Lett. **90**, 162701 (2003).