Tests of the system to measure branching ratios

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Since we announced the last improvements in our branching-ratio setup [1] we have carried out a series of thorough tests. We present here results obtained in measurements performed on a β^+ source (^{22}Na) and in an on-line radioactive beam measurement (^{38}Ca). While in the case of the ^{22}Na source the average positron energy is about 220 keV (with the main branch end-point energy, E_{max}=546 keV), in the ^{38}Ca case the average positron energy is 2430 keV (with the main branch end-point energy, E_{max}=5590 keV).

Both experiments confirm the improvement of the data throughput obtained *via* a reduction in the number of "incomplete events", events that are identified by a β-γ coincidence trigger but are missing either the γ or the β energy signal, usually because it is below the corresponding spectrum cut-off energy. (Details about the event structure are given in [1].) Table I summarizes the results obtained in measurements, each lasting about one week. The relative losses are all below 0.1%, allowing for reliable data reduction at a precision of 0.1% or better, as required [2].

Table I. Experimental losses in β-γ coincidence events.

experiment	E_β induced losses	E_γ-induced losses
^{22}Na	0.04%	0.01%
^{38}Ca	<0.1%	<0.07%

The improved data transmission should not be confused with an improved absolute detection efficiency of the β and/or γ particles: The electronics processing the corresponding signals are still subject to detection thresholds that ultimately limit the absolute efficiency of the system. This is particularly important in the case of the efficiency of the β detector, which receives a spectrum that extends down to nearly zero energy, thus making the lowest energy events impossible to disentangle from noise. However, only the relative efficiency of the β detector is important in our branching-ratio measurements, so the cut-off effects caused by the electronic threshold in the β chain are relatively unimportant.

The last remark is particularly significant in the ^{22}Na source measurement: The source measurement is convenient as an off-line test, but it places a significant part of the emitted positrons below the detection threshold; this in turn makes the measurements more dependent on the value of the threshold used to remove noise contamination. Fig. 1 presents the energy release (ΔE) spectrum as measured with the ^{22}Na positron source, along with a Monte-Carlo generated spectrum from the EGSnrc [3] simulation code. While the shape of the simulated spectrum is a good match to the experimental one, it is obvious that a significant part of the real events were not analyzed by the setup as the β energy did not exceed the threshold.

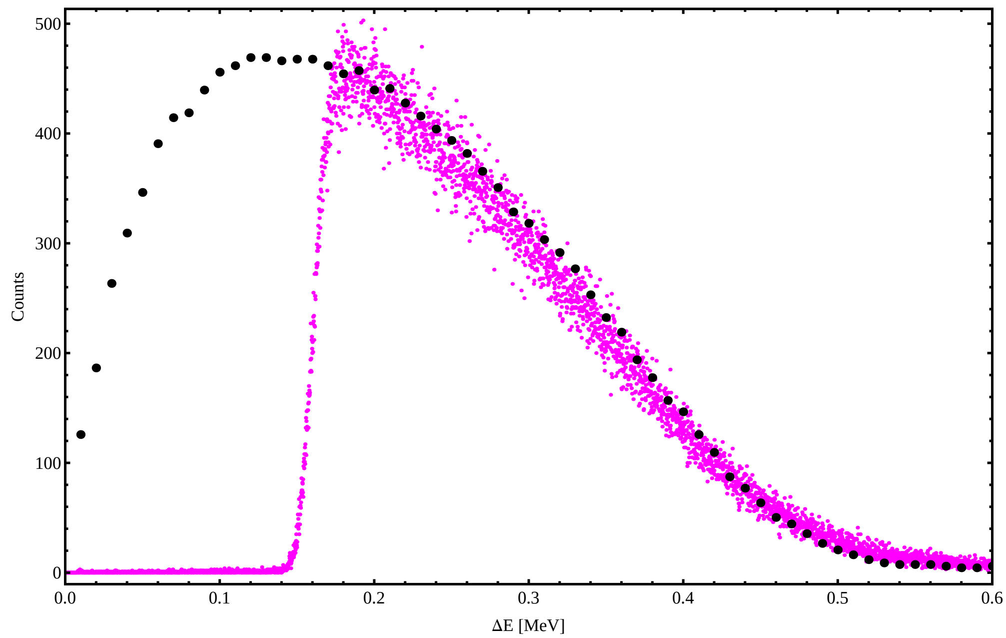

FIG. 1. Experimental ΔE spectra (tiny dots, purple) compared with Monte-Carlo generated spectra (large dots, black) for β^+ particles emitted by ^{22}Na.

This feature does not apply to the ^{38}Ca measurement. In this case the average positron energy is in the MeV region, and thus the majority of the positrons carry more energy than our 125 keV threshold. This is evident in Fig. 2, which presents a comparison of the experimental and Monte-Carlo-generated ΔE

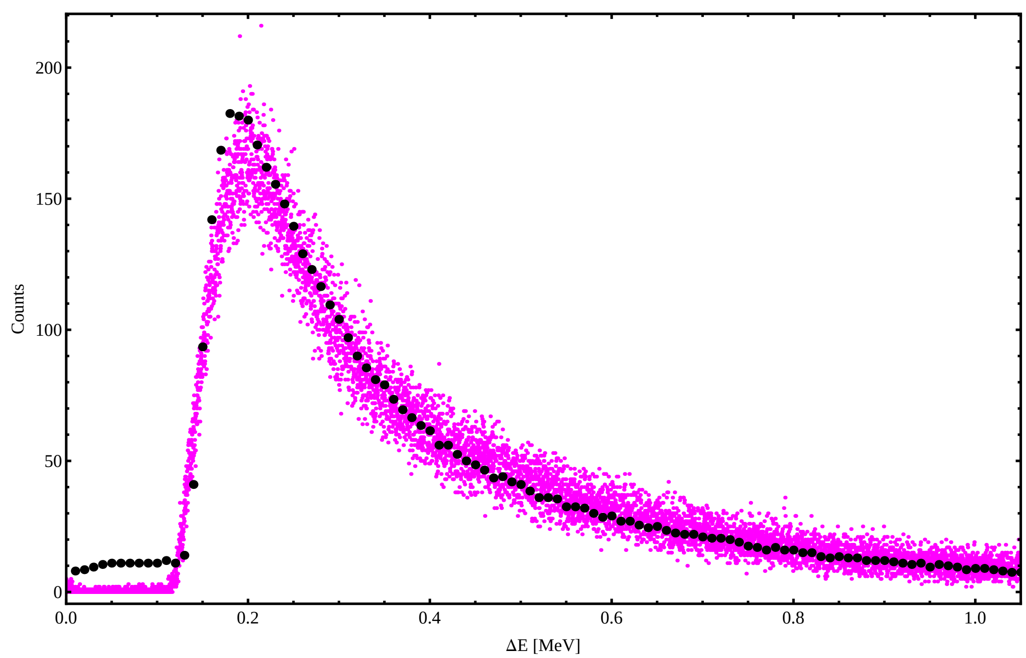

FIG. 2. Experimental ΔE spectra (tiny dots, purple) compared with Monte-Carlo generated spectra (large dots, black) for β^+ particles emitted by ^{38}Ca.

spectra for ^{38}Ca decay. A quantitative evaluation of the cut-off losses, based on the Monte Carlo simulation, is given in Table II.

Table II. Cut-off losses caused by the detection threshold.

experiment	Cut-off energy	Cut-off losses
^{22}Na	150 keV	38%
^{38}Ca	140 keV	3.5%

The improvements announced in [1] are further confirmed by the relative reduction of the "high" energy signals in the positron *ΔE* spectra: Indeed there was a dramatic reduction in the overlapping of genuine *β* signals with long tails originating from previous pulses. This explains the much better agreement between the Monte-Carlo-generated and experimental spectra, in the cases of both ^{22}Na and ^{38}Ca.

In conclusion – and most importantly for our application – the tests confirm the capability of our setup to generate reliable branching ratios at the 0.1% precision level required for superallowed *ft*-value measurements. Further details referring to the ^{38}Ca measurement are given in reference [2].

[1] V.E. Iacob, J.C. Hardy, and H.I. Park, *Progress in Research,* Cyclotron Institute, Texas A&M University (2011-2012), p. V-21

[2] H.I. Park, J.C. Hardy, V.E. Iacob, M. Bencomo, L. Chan, V. Horvat, N. Nica, B.T. Roeder, E. Simmons and R.E. Tribble, *Progress in Research,* Cyclotron Institute, Texas A&M University (2012-2013), p. I-11.

[3] I. Kawrakow, Med. Phys. **27**, 485 (2000); I. Kawrakow and D.W. O. Rogers, NRCC Report PIRS-701, NRC, Ottawa (2003); [http://www.nrccnrc.gc.ca/eng/solutions/advisory/ egsnrc_index.html].