Identifying requirements in the experimental design and analysis for isoscaling

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Isoscaling is a technique that has been used in many experiments to investigate bulk systematic trends in experimental results such as in multifragmentation [2-5], evaporation [6-8], deep inelastic collisions [8-10] and fission [11-12] experiments. The isoscaling behavior is also seen in the results of transport model calculations[13-14]. At its most basic level, isoscaling investigates the ratio of the number of particles of a given isotope emitted from two reactions as a function of proton and neutron number as such

$$R_{21} = \frac{\int \frac{dM_2}{dE}}{\int \frac{dM_1}{dE}} = C \exp(\alpha N + \beta Z). \quad (1)$$

This method of analysis is primarily used when the two reactions systems vary primarily between isospin content. We wished to investigate some of the differences between the light and heavy fragments in regards to isoscaling. To do so we used the thesis data taken by Z. Kohley and described in Reference [1]. This experiment detected fragments from both ^{64}Zn+^{64}Zn and ^{70}Zn+^{70}Zn (system 1 and 2 respectively in Equation (1)) at 35 MeV per nucleon using the 4π NIMROD array. This system was chosen due to the similar nature of the reaction and a relatively wide range in isospin content.

Many of the results of this analysis can be seen in Fig. 1. This figure shows the experimental isoscaling results for all detected particles on the left, projectile-like (PLF) fragments in the center and light emitted fragments on the right. For this analysis the PLF was determined to be the heaviest measured particle in an event. The emitted fragments are defined to be any particle that is not a PLF. Fig. 1 contains elements from boron (black circles on the left) through calcium (black squares on the right) as well as the fits to determine the value for α. The top row performs a global fit where all elements are used to find a single value while the bottom row fits each element individually.

The isoscaling analysis suggests that the ratio of these particles should be linear when plotted on a semi-log scale. This is actually a truncated form where there should also be higher order terms. A curvature in the data can be seen particularly for high Z elements showing this behavior. In order to reduce the effect of the higher orders and in order to compare our results to previous experimental results we limited our fits to only include the three most abundantly measured isotopes of any element. These are represented in Fig. 1 by the solid points, while the open points are provided as a demonstration of the effect. An identical treatment was performed to fit the β value for different isotopes of constant neutron number.

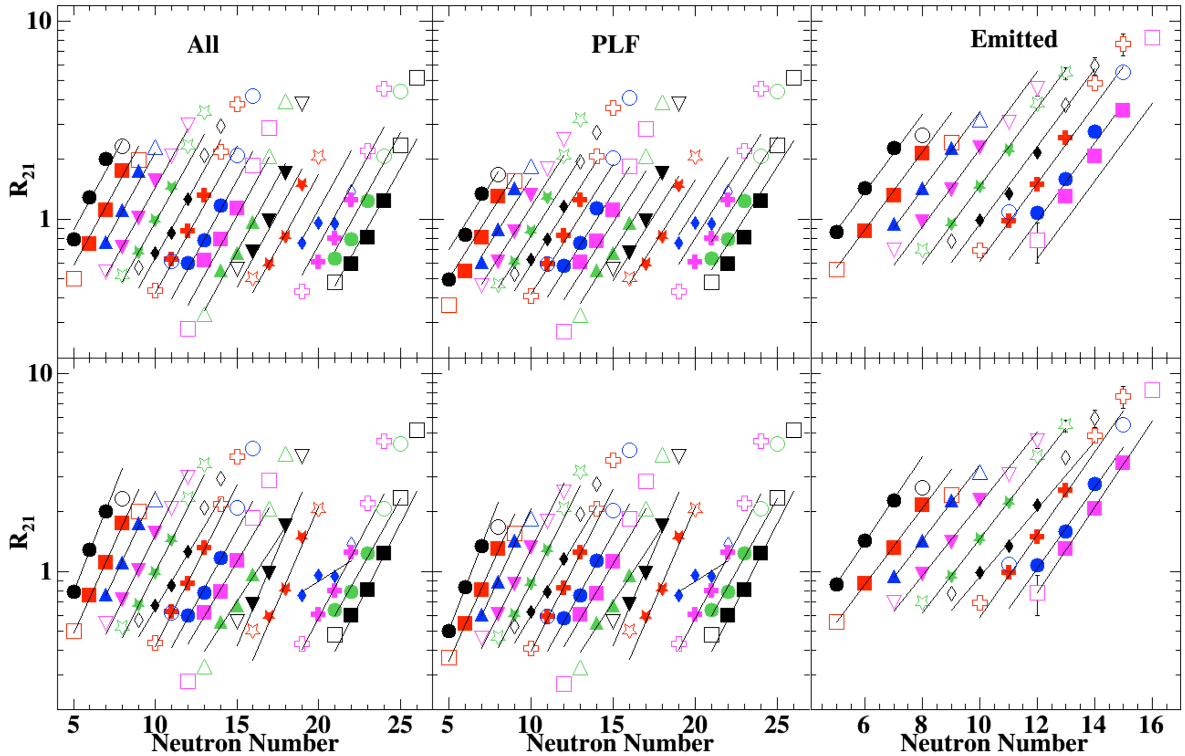

FIG. 1. The isoscaling ratios for all (left), projectile like (center), and light emitted (right) fragments with isoscaling fits included.

Naturally, the individual fits are better representations for each isotope however the global fit can still provide interesting information about the system as a whole. Fig. 2 shows the results of each of the

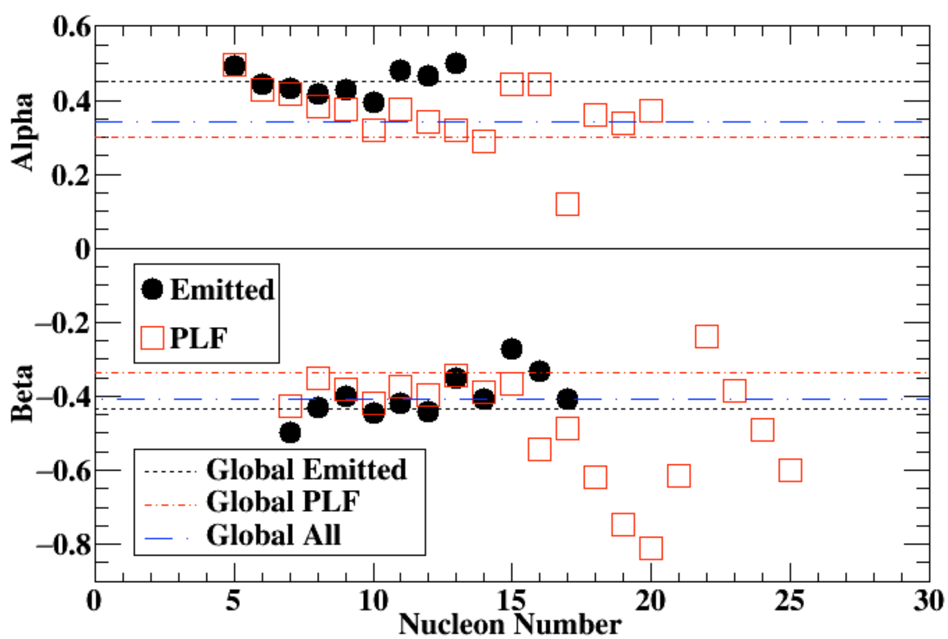

FIG. 2. The individual and global isoscaling parameters for emitted PLF and all fragments.

individual fits in comparison with the global fits. Interestingly, the emitted particles result in higher values of the R_{21} value as well as α values than the PLF counterparts. Of particular interest is which type of particle dominates the global fits for the two isoscaling parameters. For the α parameter, the global fit for all particles is driven primarily by the PLF while the emitted fragments seem to dominate for the β parameter.

This difference leads us to an important distinction that needs to be made in the experimental design and analysis when isoscaling is intended to be used. In this experiment, due to the relatively small size of the zinc isotopes, it was quite possible to have isotopes in the range of carbon to oxygen, for example, be either a PLF or an emitted fragment in not insignificant quantities. Without the NIMROD array and the ability to discern the PLF on an event by event basis, our results would show isoscaling parameters for emitted particles that are affected by the PLF. This would provide inaccurate values for those parameters which can contribute to inaccurate results which derive from those values.

There are two ways that experiments can minimize this effect. An experiment can use a nearly 4π detector to identify as many of the fragments as possible to ensure the removal or particular selection of the PLF on an event by event basis. The other option would be to design the experiment using a rather large system and primarily detecting the PLF to make those comparisons, or by only analyzing a range of isotopes where the likelihood of those fragments being the PLF is quite low. These methods would either prevent or minimize cross contamination between the two types of particles in order to ensure as true a comparison as possible and receive the more accurate results.

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