# Direct mass measurement of $^{53}$Ni and first test of IMME in fp-shell nuclei*

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New mass measurements were conducted at the storage ring CSRe in Lanzhou, employing the isochronous mass spectrometry (IMS) technique [1, 2]. Nuclides of interested were produced in projectile fragmentation of $^{58}$Ni primary beam. Masses of a series of short-lived neutron-deficient nuclides including $^{41}$Ti, $^{45}$Cr, $^{49}$Fe and $^{53}$Ni were measured with a typical mass uncertainty of 30 keV/c$^2$ [5]. The measured revolution time spectrum is illustrated in Figure 1.

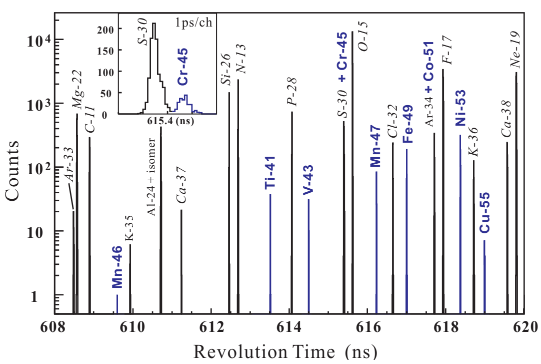


Figure 1: The revolution time spectrum of neutron-deficient $^{58}$Ni projectile fragments. The insert shows the well-resolved peaks of $^{30}$S and $^{45}$Cr nuclei. Nuclei with masses determined in this experiment and those used as references are indicated with bold and italic letters, respectively. Adopted from Ref. [5].

New data enabled us to perform the first ever test of the Isobaric Multiplet Mass Equation (IMME) in fp-shell nuclei [5]. Based on the concept of isospin symmetry, the states in nuclei can be classified according to the isospin quantum number $T$ with a projection $T_z = (N - Z)/2$. Assuming the two-body nature for any charge-dependent effects and the Coulomb force between the nucleons, the masses of $2T + 1$ members of an isobaric multiplet are related by the isobaric multiplet mass equation (IMME) [3, 4]. To test a possible deviation of the IMME from the predicted parabolic form, described by polynomial coefficients $a$, $b$ and $c$, an additional cubic term with coefficient $d$ can be considered.

Experimental $d$-coefficients obtained in this work are plotted in Figure 2 together with precision data on lighter nuclei, see Ref. [5] and references cited therein. A $3.5\sigma$ deviation from the parabolic shape is observed for $A = 53$ isobaric multiplet, which is a striking result.

This large $d$ coefficient cannot be explained by either the existing or the new dedicated theoretical calculations of isospin mixing. If this breakdown of the IMME is confirmed by improved experimental data, both the new ground-state masses as well as the energies of the isobaric analog states, possible reasons, such as enhanced effects of isospin mixing and/or charge-dependent nuclear forces in the $fp$-shell, should be investigated.

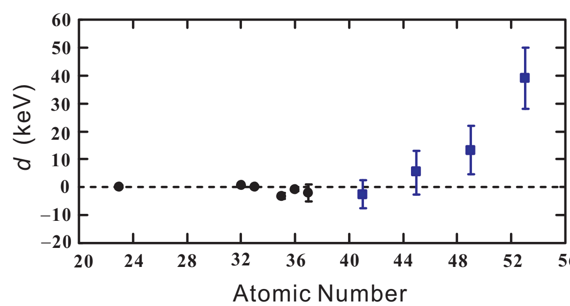


Figure 2: $d$ coefficients for the four $T = 3/2$ isobaric multiplets in $pf$-shell (squares). Data for lighter nuclei (circles) are shown for comparison. Taken from Ref. [5].

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