Mass and charge identification of exotic nuclei with intermediate energy

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Introduction: The unexpected disappearance of traditional landmark nuclear properties in neutron rich *sd-shell* nuclei has been a topic interest for long. In 1975, Thibault et. al. [1] first pointed (via mass measurements) the unexpected high binding energies in ^{31,32}Na. Similar effects were subsequently observed in neutron-rich Ne and Mg isotopes. Recently, we have performed an experiment to explore these neutron rich exotic nuclei around N~20 "Island of Inversion" through electromagnetic excitation [2]. The exclusive set-up for kinematically complete measurement, the ALADIN-LAND setup at GSI, Darmstadt was used for this purpose. The data analysis of that experiment (S306) is in an advanced stage of various detector calibration. In this article, identification of mass of exotic nuclei after secondary reaction will be presented.

Experiment: A cocktail beam of neutron rich exotic nuclei ($^{34-35}$Al, $^{31-33}$Mg, $^{29-30}$Na) (Fig.1(left)) at ~470MeV/u were allowed to undergo reaction using different secondary or reaction targets. Pb targets were used for electromagnetic excitation while reaction with CH_2 target helped in understanding nuclear contribution in the reactions. Kinematically complete measurements of all the reaction products were performed using the extensive ALADIN-LAND setup (Fig. 1). Mass of the reaction fragments were analyzed using A LArge DIpole magNet (ALADIN) placed after the secondary target. Charge of the reaction fragments were measured using the Time of Flight Wall (TFW). Position information were extracted from the Silicon Strip Trackers (SSTs) and Glass Fibre detectors (GFIs) placed before and after ALADIN, respectively.

Analysis: Data analysis is being performed using CERN-ROOT platform and *land02* framework with modification from SINP group. Calibration of TFW and SST detector has already been presented in Ref. [3] and [4],

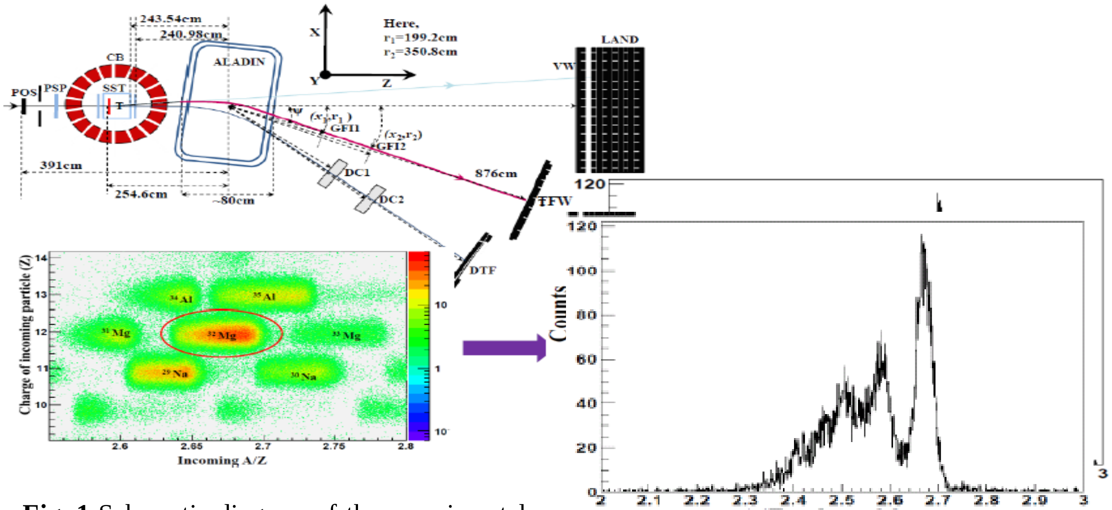

Fig. 1 Schematic diagram of the experimental set-up (insight left) Incoming Particle ID with CUTG on ^{32}Mg (insight right) Mass spectra of outgoing fragments .

respectively. The position resolution (σ_x) of the GFI detectors obtained after calibration was 3.18 ± 0.14 mm. Now, if x_i be the position measured by the i^{th} GFI and r_i, X_{0i} be its distance from centre of ALADIN and arch- length to its origin, respectively (as shown in Fig. 1), the deflection angle of the charged fragments through ALADIN can be written as

$$\psi = \frac{(x_1 - x_2) + (X_{01} - X_{02})}{(r_1 - r_2)}$$

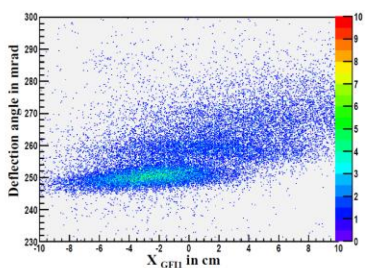

Fig. 2 2-dimensional spectrum of GFI angle against GFI x-position measurement.

Different patches corresponding to different outgoing nuclei were observed in the plot of deflection angle against x-position measured by GFI. These patches had a slope due to misalignment. Fig. 2 shows the same 2D-plot, but after correction. This deflection was used to measure the radius of curvature (ρ) of the charged fragment through ALADIN.

$$\rho = \frac{L}{2.\sin\left(\psi/2\right).\cos\left(\alpha - \psi/2\right)}$$

Here, L is the effective length of the magnetic field and α the tilting angle of ALADIN. Now, one may use the magnetic rigidity relation to get the fragment mass to charge ratio as

$$\frac{A}{Z} = \frac{B.\rho}{\beta.\gamma}$$

Where, Z is the charge of the reaction fragments measured by the TFW detector, β the fragment velocity measured using ToF between two scintillator detectors POS and TFW, γ is the Lorentz factor. Finally, one can find the mass of the outgoing fragments with the consideration of a particular reaction channel as shown in Fig. 1(insight left).

Nuclei	σ(A)	Nuclei	σ(A)
^{35}Al	0.278±0.010	^{30}Mg	0.277±0.029
^{34}Al	0.451±0.037	^{29}Na	0.179±0.007
^{32}Mg	0.220±0.006	^{28}Na	0.347±0.012
^{31}Mg	0.303±0.015		

Table. 1 Mass resolution of different nuclei obtained from this experimental data

The obtained mass resolution for different nuclei have been shown in Table 1. Calibration of the neutron detector LAND is going on for the accurate measurement of the one neutron removal cross-section of these “Island of inversion” nuclei which will be important for understanding exotic nuclear structure.

References:

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[4] http://sympnp.org/proceedings/56/E74.pdf.