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GANIL P 94 23

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Abstract :

We report on the production of the doubly magic nucleus ^{100}Sn and other proton-rich nuclei in the A~100 region in the reaction ^{112}Sn + ^{nat}Ni at 63MeV/A. The high acceptance device SISSI, the magnetic spectrometers Alpha and LISE3 at GANIL were employed for the collection, separation and in-flight identification of the different reaction products. The measurements of time-of-flight, energy-loss and kinetic energy at event by event mode allow the mass A, atomic number Z, and charge Q determinations of the reaction products. Over twenty events of ^{100}Sn^{48+} were observed over a period of 44 hours with a primary beam intensity of ~ 2.4pnA.

1- Scientific motivation :

Recently, in April 1994, a first observation of ^{100}Sn was reported [1] in experiment with a 1.1GeV/A ^{124}Xe beam. Also in April 1994, ^{100}Sn was identified in projectile-fragment separator based experiment at GANIL. On this symposium, we report on this last result. The full description of the experiment is published in [2] for ^{100}Sn and will be published in [3] for other new nuclei.

The ^{100}Sn nucleus, very far from the stability line, is expected to be the heaviest N=Z nuclear system stable against a ground-state proton decay [4]. Theoretical predictions give a half-life $T_{1/2} \sim 0.5$ s. [5], a high decay energy Q_{EC} greater than 7 MeV [6], a proton separation energy Sp less than 3MeV[6], and a large shell energy gap of about 6.5 MeV [7].

The studies of N=Z and neighboring nuclei in the ^{100}Sn region give information about :

- Magicity of the double closed shell far from the stability line.
- Interaction between protons and neutrons occupying the same shell-model orbits.
- Gamow-Teller (GT) beta decay : $\pi g_{9/2} \dashrightarrow \nu g_{7/2}$ [5].

2- Reaction's choice :

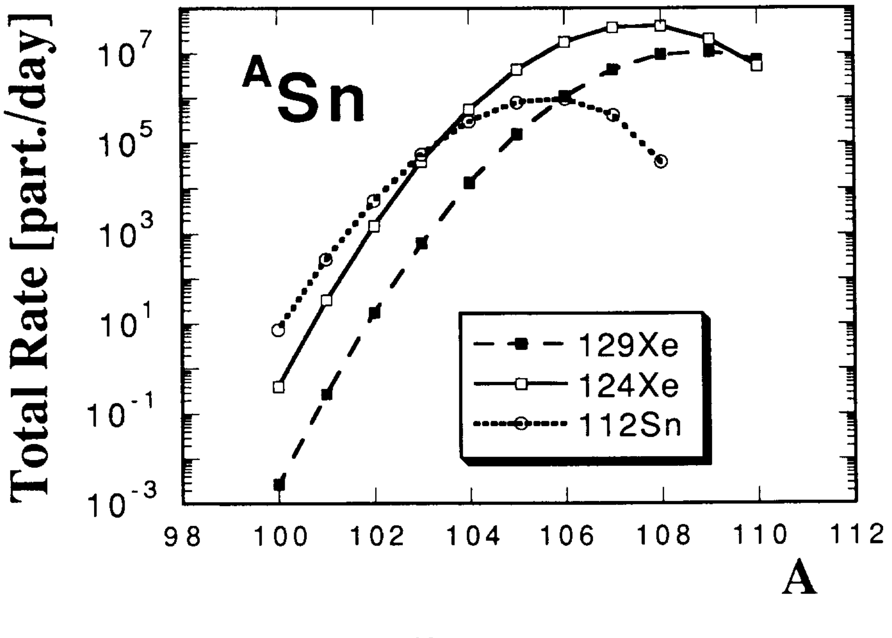

Fig. 1 : Comparison of expected rates of ^{100}Sn per day, predicted by the LISE program, for ^{112}Sn (58MeV/A), ^{124}Xe (44MeV/A) and ^{127}Xe(44MeV/A) incident beams onto Ti target.

To enhance the production of neutron-deficient isotopes, a beam of 63MeV/A of the lightest stable tin isotope ^{112} Sn and a natural Ni target (68.3% ^{58}Ni, 144mg/cm^2) were used. The Nickel target was chosen to favorise a high proton to neutron ratio of reaction products and to enhance a cross section for transfer-type reactions. The rare primary beam ^{112}Sn is developed at GANIL in a close and very fruitful collaboration with the Flerov Laboratory of Nuclear Reactions, JINR at Dubna. Fig. 1. shows the comparison of expected rates of ^{100}Sn per day, predicted by the LISE program [8], for ^{112}Sn (58MeV/A), ^{124}Xe (44MeV/A) and ^{127}Xe(44MeV/A) incident beams onto Ti target.

3- Charge state and bρ optimization :

In a first experiment (^{112}Sn, 58MeV/nucleon) using the LISE3 spectrometer, we measured a charge state distribution of ^{112}Sn as reported in fig. 2. : The charge state distribution of the primary beam after the Ni target was peaked in Q=49$^+$ and Q=48$^+$.

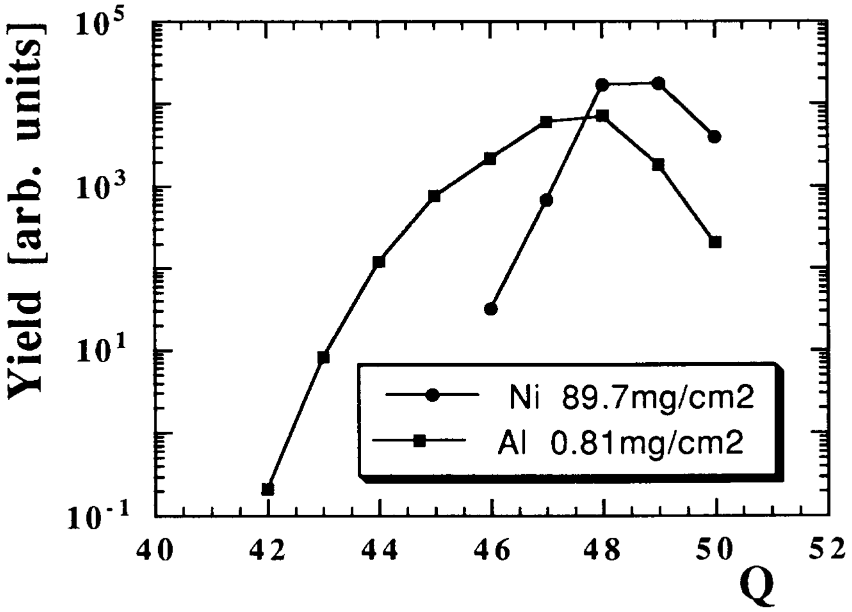

Fig. 2 : Charge state distribution of ^{112}Sn (58MeV/A) after 89.7mg/cm^2 ^{nat}Ni target with 9.5 mg/cm^2 ^{12}C foil and after 0.81mg/cm^2 Al foil.

Systematic and quantitative measurements [9] were perfomed for the reaction products in order to determine the most abundant charge state and the best brho setting. The production of $^{101-110}$Sn was measured for different charge states and Brho settings. As a consequence in the main experiment performed at the primary beam energy of 63MeV/A, the charge state Q=Z-2 was chosen and a Brho value of 1.876 Tm. were used to select ^{100}Sn.

4- Experimental setup :

Figure 3 shows the experimental setup used for the identification of ^{100}Sn and neighboring nuclei.

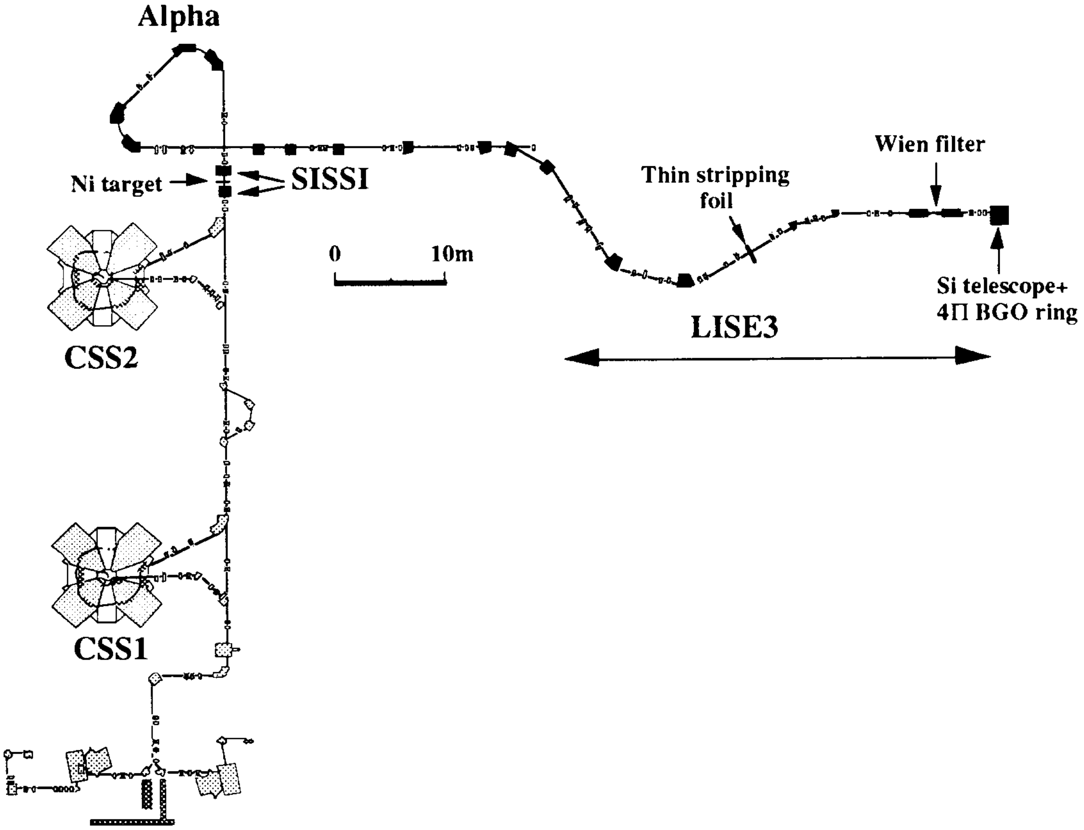

Fig. 3 : Schematic diagram of the experimental facilities at GANIL used to produce and identify ^{100}Sn.

4-1 High acceptance device SISSI :

A beam of 63MeV/nucleon of ^{112}Sn^{46+} with an intensity about 110 enA bombarded a 144mg/cm^2 Ni target placed in the high acceptance device SISSI (Source d' Ions Secondaires à Solénoïdes Intenses) [10] : A first superconducting solenoid before the target, focusses the incoming beam on the target, producing a very small spot, (ϕ 0.3mm) a second superconducting solenoid with a big angular acceptance collects and refocusses the reaction products. A gain in acceptance of an order of magnitude was obtained compared to the preliminary experiment with LISE3.

The $B\rho$ analysis of outgoing fragments was performed by the Alpha[11] and LISE3[12] spectrometers.

4-2 New selection by stripping foil :

To reduce the rate of the light, fully stripped fragments arriving at the final focus of LISE3, a thin mylar foil (1.5µm.) was placed at the intermediate focal point. The role of this foil was to change the charge states of heavy fragments without modifying their velocities. Light fragments, however, remained fully stripped. A change of about 2% in $B\rho$ and a corresponding aperture of the $B\rho$ slits in the second section of LISE3 reduces strongly the transmission of fully stripped ions and favors that of heavy ones. The remaining unwanted particles were further eliminated by a velocity selection, using the Wien filter [12] located at the end of LISE3.

4-3 Detection :

All selected nuclei were stopped at the last image point of the spectrometer in a telescope consisting of four silicon detectors E1(300µm), E2(300µm), E3(300µm) and E4(500µm) providing energy-loss (ΔE), and total kinetic energy (TKE). Since the ions in the mass region of interest were stopped in the E2 detector, an anticoincidence with the last two silicons was also required. The time of flight (TOF) was measured using a start signal provided by the first Si detector and a stop signal derived from the radio-frequency of the second cyclotron. The magnetic rigidity of the dipoles was measured with nuclear magnetic resonance probes. Finally, a segmented 4Π BGO ring [13] surrounding the implantation detector (50% efficiency at 511keV.) was used for detection of prompt gamma-rays to reject events corresponding to reactions in the detectors.

5- Data analysis :

The atomic number is determined by a combination of the energy-loss in the Silicon detector ΔE and time-of-flight (TOF) measurements according to the Bethe formula:

$$Z \sim \sqrt{\Delta E / \left(\frac{1}{\beta^2}\ln\left(\frac{5930}{1/\beta^2-1}\right)-1\right)}$$

The charge state Q of each isotope is calculated from the relativistic relation :

$$Q = 3.33\times10^{-3}\frac{TKE[MeV]\beta\gamma}{B\rho[Tm](\gamma-1)}$$

The mass A of each nucleus expressed in a.m.u. is extracted from the equation:

$$A = \frac{B\rho[Tm]\,Q}{3.105\,\beta\gamma}$$

To provide very careful calibrations for the energy-loss, total kinetic energy and time-of-flight measurements, the primary ^{112}Sn beam with different charge states from Q=46$^+$ to Q=50$^+$ and different energies, were transmitted by changing the angle of target, without modifying the magnetic rigidity of the beam line. This calibration, which is valid for nuclei in the region of interest, takes into account non linear effects in the electronic chains and the silicon detectors.

6- Results :

6-1 Production and identification of ^{100}Sn :

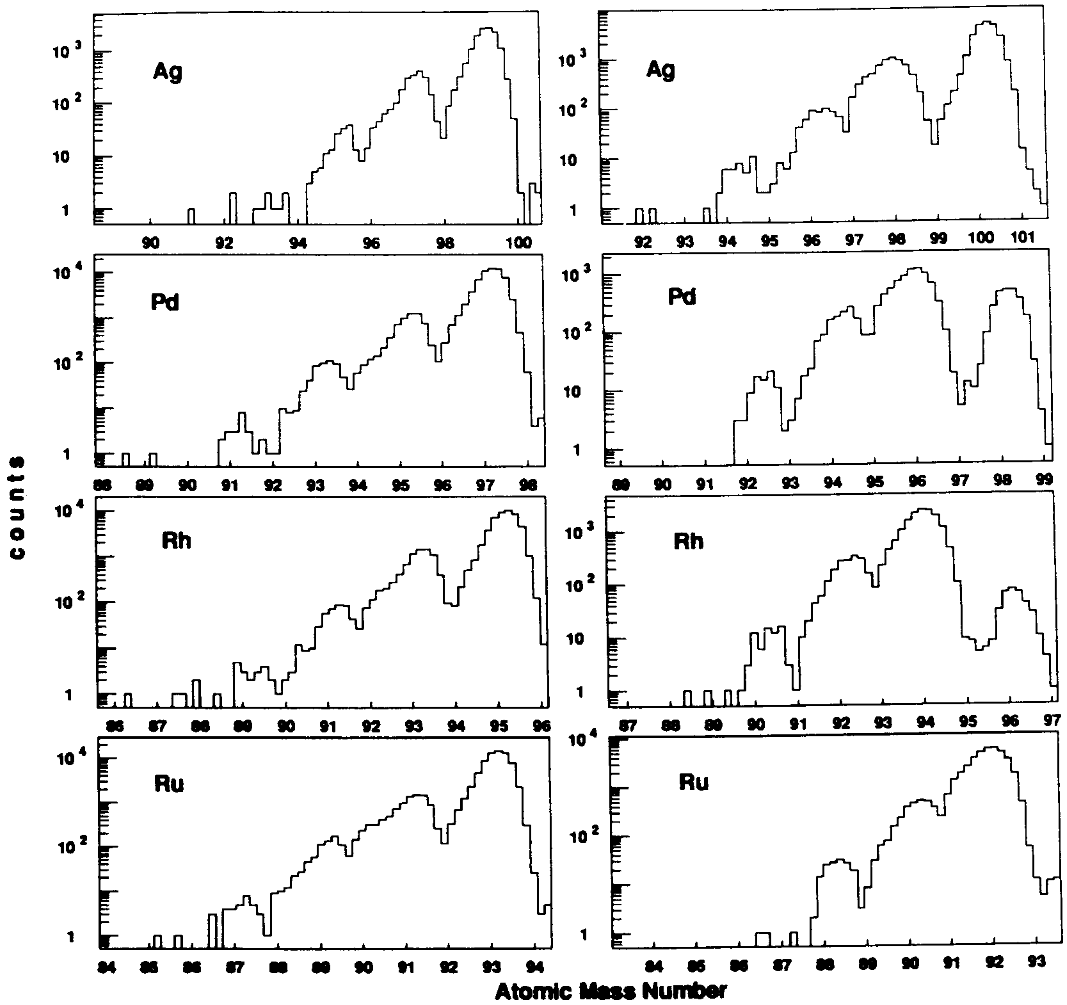

Fig. 4.a : Mass' distribution of very neutron-deficient Ag, Pd, Rh, and Ru isotopes produced with ^{112}Sn beam at 63MeV/A.

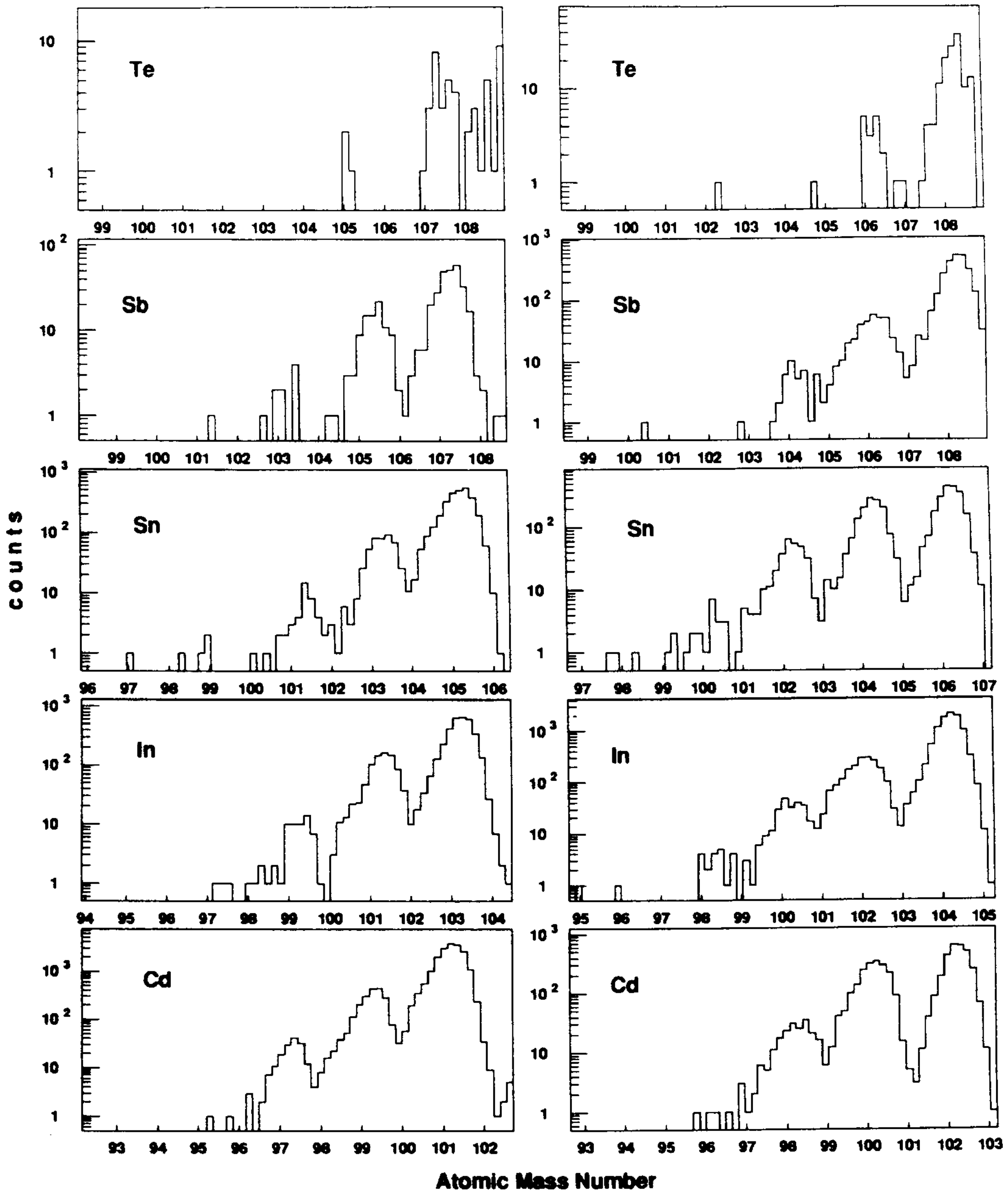

Fig. 4.b : Mass' distribution of very neutron-deficient Te, Sb, Sn, In and Cd isotopes produced with ^{112}Sn beam at 63MeV/A.

In fig. 4a and 4b, the mass' distributions of Cd, In, Sn, Sb, Te, Ag, Pd, Rh, Ru nuclei selected from Z and A/Q determinations are presented. Over twenty events (summing events found in Q=47^{+} and Q=48^{+} charge states) corresponding to ^{100}Sn were observed over a period of 44 hours. Production rates for 100Sn are promising for future half-life and mass measurements. Other nuclei as ^{87}Ru, ^{89}Rh, ^{91}Pd, ^{98}In, ^{103,104}Sb were also identified in this experiment for the first time.

6-2 Search for the isomeric states :

In the preliminary experiment [14] at 58MeV/A incident energy, four large volume (80%-90%) germanium detectors and a NE102 plastic scintillator surrounded the final telescope ; they served for measurements of beta and gamma radiation coming from the nuclei implanted in the Silicon detectors. Fig. 5 presents characteristic rays of isomeric states decay observed in coincidence with respective heavy ions. In the second experiment, gamma-rays were detected in the BGO ring in coincidence with heavy fragments. Their analysis is in progress.

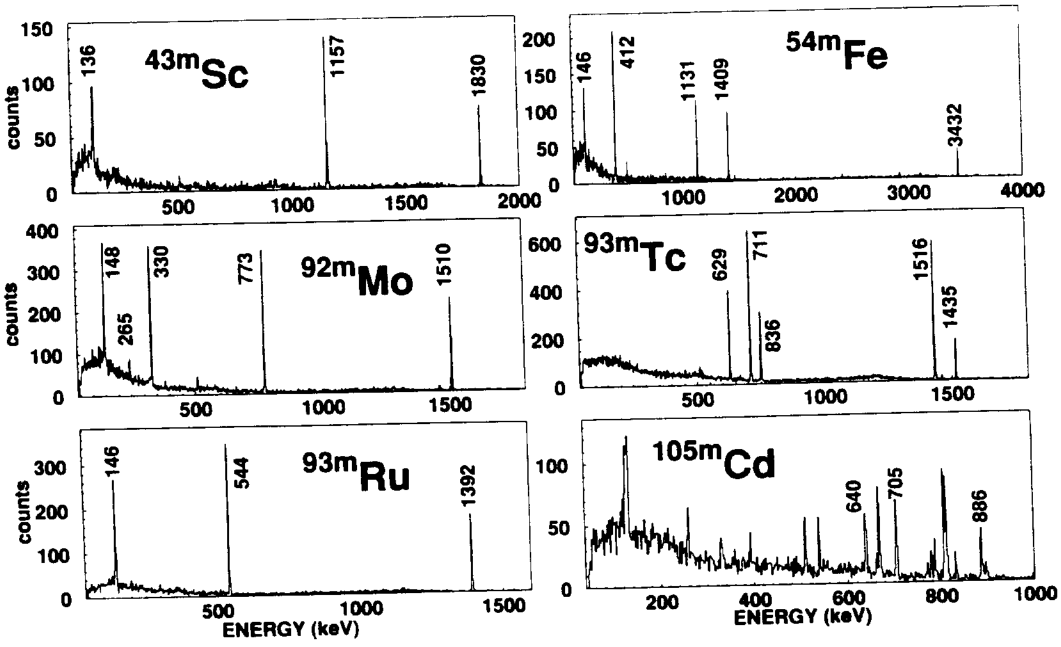

Fig. 5 : γ-ray spectra following the decay of the isomeric states in a few selected nuclei implanted in the Silicon detectors.

7- Conclusion : Border line of known nuclei near ^{100}Sn :

Fig. 6 displays a section of the chart of nuclei near ^{100}Sn. The last known nuclei are ^{89}Rh [3], ^{91}Pd [3], ^{94}Ag [15,16], ^{97}Cd [17], ^{98}In [18], ^{100}Sn [1,3] ^{103}Sb[3], and ^{106}Te[19]. The theoritical drip line (calculated with the empirical mass formula of Tachibana[20]) is reached for In and Ag isotopes, and is crossed already for Sb and Rh isotopes.

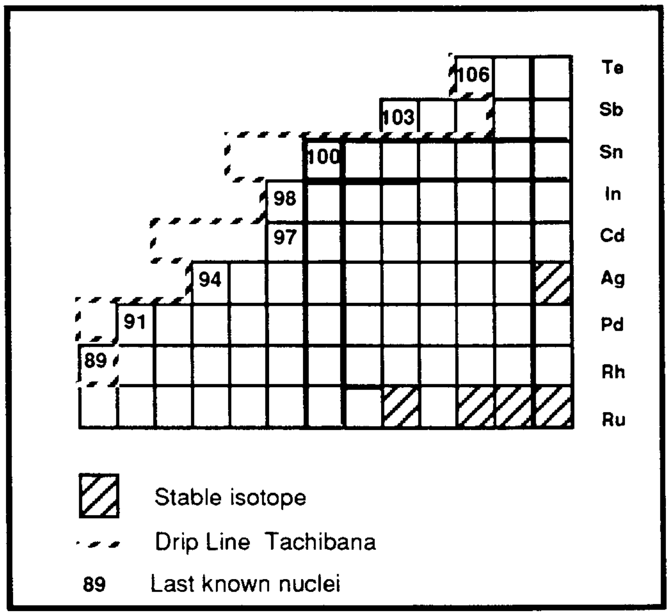

Fig. 6 : Part of the chart of nuclei near doubly magic ^{100}Sn

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