Application of detection and technological systems for synthesis of SHE in the ^{48}Ca induced complete fusion reactions

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Introduction

One of the fundamental outcomes of the nuclear shell model is prediction of existence of the "Island of Stability" in the domain of the super heavy elements. This hypothesis has been under development for more than 35 years in various nuclear models. It is the Dubna Gas Filled Recoil Separator (DGFRS) that allows to perform a set of successful experiments aimed to synthesize super heavy nuclides with Z=112-118 experiments. It has become possible only with application:

a) the detection system of the DGFRS ;
b) method of "active correlations" for radical suppression of background reaction products;
c) Integral monitoring/control system to provide the experiment parameter monitoring and highly radioactive actinide target protection during the long term experiments.

Detection system of the DGFRS

For the synthesis and study of heavy nuclides, the complete fusion reactions of target nuclei with bombarding projectiles are used. The resulting excited compound nuclei (CN) can deexcite by evaporation of some neutrons, while retaining the total number of protons. Recoil separators are widely used to transport EVRs from the target to the detection system, while simultaneously suppressing the background products of other reaction, incident beam of ions, and scattered target nuclei. A distinctive feature of gas-filled separators is the fact that atoms recoiling from the target with the broad distribution of high charge states interact with the gas such that both average charge and dispersion are reduced. The decrease of average charge of EVRs results in their larger rigidity in the magnetic field in comparison with the background ions. Thus, EVRs can be rapidly separated in flight from unwanted reaction products and collected at detection system. From the viewpoint of the separator design D-Q-Q (dipole magnet and two quadrupole lenses) is applied. The simple but new idea of the algorithm is aimed at searching in real-time mode of time-energy-position recoil-alpha links, using the discrete representation of the resistive layer of the position sensitive PIPS detector separately for signals like "recoil" and "alpha-particle". So, the real PIPS detector is represented in the PC's RAM in the form of two matrixes, one for the recoils (static) and one for alpha-particles (dynamic). Those elements are filled by values of elapsed times of the given events. The second index number of the matrix element is defined from the vertical position, whereas the first index is in fact strip number (1…12). In each case of "alpha-particle" detection, a comparison with "recoil"-matrix is made, involving neighboring elements (+/-3). If the minimum time is less or equal to the setting time, the system turns on the beam chopper which deflects the heavy ion beam in the injection line of the cyclotron for a 1-5 min. The next step of the PC code ignores the vertical position of the forthcoming alpha-particle during the beam-off interval. If such decay takes place in the same strip that generated the pause, the duration of the beam-off interval is prolonged up to 10-30 min. In the Fig.1 a,b schematic of the algorithm and flowchart of the method application are shown.

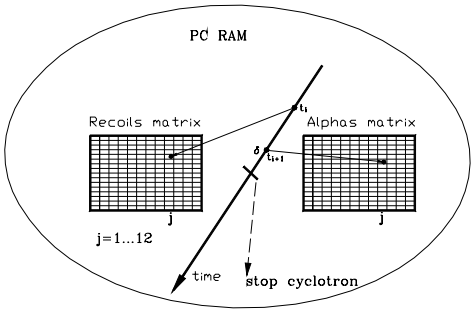

Fig.1a Schematic of the algorithm. ER and alpha-particle matrixes are shown.

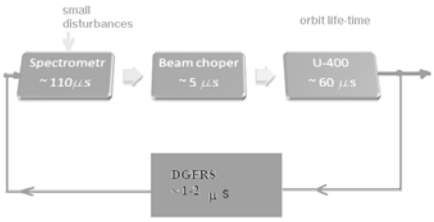

Fig.1b Flowchart of the beam-interrupting process

Parameter monitoring system of the DGFRS

PC-based (CAMAC) one-crate control system of the Dubna Gas Filled Recoil Separator is developed [4] for the long-term experiments at the U400 FLNR cyclotron and is aimed at the synthesis of super heavy nuclei in heavy ion induced complete fusion reactions. Special attention is paid to generating the "alarm" signals and implementing further the appropriate procedures. Usually, a list of parameters/signals includes the following :

- Dipole, quadruples current values measurements as well as setting of alarm thresholds;
- Rotation speeds both entrance window and radioactive target wheels;
- Pressure value in working area of the DGFRS and pentane pressure value in the TOF (time-of-flight module);
- Temperature parameters;
- Beam associated parameters;
- Vacuum parameters;
- Pressure of saturated vapor of pentane in liquid pentane volume
- Photo-diode rotation target output signal amplitude

Examples of application

During the last 8 years the mentioned method was successfully applied in the HI induced nuclear reactions:
$^{238}U + {}^{48}Ca \rightarrow {}^{286-x}112 + xn$, $^{242,244}Pu + {}^{48}Ca \rightarrow {}^{290,292-x}114 + xn$, $^{245,248}Cm + {}^{48}Ca \rightarrow {}^{293,296-x}116 + xn$; $^{243}Am + {}^{48}Ca \rightarrow {}^{291-3,4}115 + 3,4n$, $^{237}Np + {}^{48}Ca \rightarrow {}^{282}113 + 3n$, $^{249}Cf + {}^{48}Ca \rightarrow {}^{294}118 + 3n$, $^{249}Bk + {}^{48}Ca \rightarrow 117 + 3,4n$, $^{226}Ra + {}^{48}Ca \rightarrow {}^{270}Hs + 4n$.

For example, in the Fig.2 the result of application is shown for **$^{249}Bk + {}^{48}Ca \rightarrow 117 + 3n$** complete fusion reaction [5]. Due to search for first ER-α correlation chain in a real-time mode, the forthcoming decays were detected in background free mode.

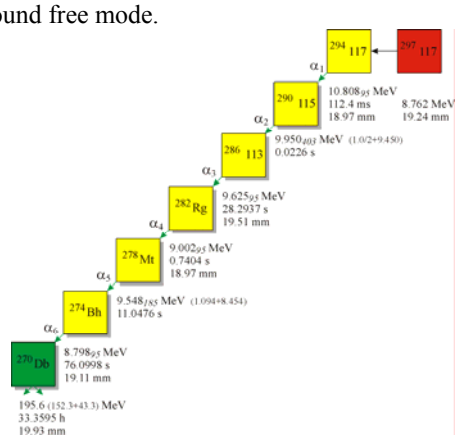

Fig.2 Chain of Z=117 nuclei measured in the experiment [5]

References

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