Recoil filters for active correlations method: different scenarios

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Abstract

New approach to the life – time estimation for recoil-alpha detected times is presented. Brief description of the Dubna Gas-Filled Recoil Separator (DGFRS) detection module is presented too. This approach will be used for real-time detecting “active correlations” method with nearest future commissioning of new FLNR (JINR) DC-280 extremely high intense heavy ion cyclotron in the year 2017.

1. Introduction

With commissioning new FLNR (JINR) DC-280 cyclotron in 2017 new requirements are arising in the “active correlation” method [1-4] application to suppress beam associated background signals [5]. One of the is to take into account an influence of background signals to a measured value of live time parameter in a real time mode via detection time-energy-position \( ER-\alpha \) correlation chain to stop an actinide target irradiation process for a short time. Some approaches to that problem, to some extent, are reported in [5,6].

In the present paper, some attempt is made to use a more careful method taking into account background signals imitating both alpha and recoil true signals.

2. Detection module of the DGFRS

Significant success has recently been achieved in the field of SHE synthesis and studies of radioactive properties of superheavy nuclei. With the discovery of the “island of stability” [7] in experiments with \(^{48}\text{Ca}\) projectiles at the DGFRS, one can raise a question about sources and components of such a great event. Intense heavy-ion beams and exotic actinide target materials were certainly strongly required in experiments. However, final products of the DGFRS experiments were rare sequences of decaying nuclei signals. In this connection, the role of the DGFRS detection
systems was crucial. Specifics of the DGFRS detection system is application of the “active correlations” method [1–4]. Using this technique, it has become possible to provide deep suppression of background products with negligible losses in the value of the whole experimental efficiency. Moreover, experiments at the DGFRS, when the above-mentioned method was not applied, yielded ambiguous results [8]. To briefly clarify method application, a process block diagram is shown in Figure 1a-c. A short beam stop was generated by the EVR-α sequence detected in real-time mode.

Note that in most of the DGFRS experiments one of the two first alpha particle signals was used as a trigger signal for a break point in target irradiation.

![Diagram](image1.png)

**Fig.1a.** Schematics of the real-time process to search for ER-α sequence. Parameter 60 µs is corresponded approximately to the orbit life time for $^{48}$Ca ion in main FLNR U-400 cyclotron, 40 µs – dead time of CAMAC electronics.

![Diagram](image2.png)

**Fig.1b.** The DGFRS detection module (schematically). Proportional chambers “start”/“stop”, and focal plane Double Side Silicon Strip Detector (48x128 strips, Micron Semiconductors, thickness ~300 µm, full depletion) are shown. Low pressure pentane filled (vapor pressure 1.6 Torr) gaseous detector creates three signals: TOF (time-of-flight and two $\Delta E$ signals with limited proportionality). An implantation path of ER from a target onto DSSSD detector is shown by an arrow too.
1. An exponential weight function #1

In this case the a weigh function can be written as: $W_i = e^{-\frac{t_i}{\tau}}$.

As it was shown in [5] the equation for an optimal life-time parameter for beam stop will be:

$$\tau = \frac{w_1 t_1 + w_2 t_2}{w_1 + w_2} = t_1 e^{-\frac{t_1}{\tau}} + t_2 e^{-\frac{t_2}{\tau}}.$$ 

In the Ref.[5] it was shown that few microseconds does it takes for solution with 2-4% precision or even less if one take mean geometry value parameter $\tau_0 = \sqrt{t_1 t_2}$ a first approximation. Note, that both Newton and simple iterations methods gave nearly the same timing results for 3GHz CPU of PC (Fig.2).

Case of “integral filter” $W_i = 1 - e^{-\frac{t_i}{\tau}}$, was considered in [5] too. Of course, an influence of background signals may be taken into account (see below). And it is easy to extend the above approach to the case of n-recoils.
2. Weight function #2

Let us consider function like:

\[ w(t_i, \tau) = F(bg) \cdot e^{-\frac{t_i}{\tau}} \cdot (1 - e^{-\frac{t_i}{\tau}}). \]

In that equation [5] it taken into account, in the form of empirical fact, that both factors to register a signal in the o(t_i) and in the interval (0,t_i) are considered to be the same weight.

Function F(t,\tau) may be considered as a factor for the measured ER-\alpha chain to be non-random. For the Poisson like process probabilities for true recoil to correlate with one or more random signals imitating alpha decay and for true \alpha to correlate with one or more recoil imitating signals are

\[ 1 - e^{-\frac{t}{<t_{\alpha}>}} \quad \text{and} \quad 1 - e^{-\frac{t}{<t_{ER}>}}, \]

respectively.

Therefore,

\[ F(bg) \approx \left(1 - (1 - e^{-\frac{t}{<t_{\alpha}>}})\right) \cdot \left(1 - (1 - e^{-\frac{t}{<t_{\alpha}>}})\right). \]

If one introduces a parameter of effective background signal time \( \tau_{eff} \) as

\[ \frac{1}{\tau_{eff}} = \frac{1}{<t_{\alpha}>} + \frac{1}{<t_{ER}>}. \]

The resulting equation can be rewritten in the form as:

\[ w(t_i, \tau) = e^{-\frac{t_i}{\tau_{eff}}} \cdot e^{-\frac{t_i}{\tau}} \cdot (1 - e^{-\frac{t_i}{\tau}}). \]

Here, \( t_i \) – the registered time value (from CAMAC electronics or/from Windows high precision timer API function) for ER-alpha sequence, \( <t_{\alpha,ER}> \) - mean times for alpha and recoil imitator signals, respectively, \( \tau \) - life time of the nuclide (parameter which have to find).

3. An alternative (additional) scenario

An additional way to decrease beam stop number is to use a higher correlation level of ER-\alpha real-time searching procedure. For instance,

\[ ER \cap \alpha_1 \cap \alpha_2 \quad \text{except for} \quad ER \cap (\alpha_1 \cup \alpha_2). \]

As a drawback it will decrease the whole detection efficiency. As concerns to those approaches related with the new FLNR gas-filled separator design, they are outside the scope of this paper. Using a combined mode, when one can in parallel
use ER signal to create a shorter beam-off time interval is a reasonable scenario too. The block diagram of the process is shown in the Fig.3.

![Block diagram](image)

**Fig.3** An alternative scenario block diagram; $t_1$ parameter in the figure denotes short interval value after detection of each recoil signal.

3. **Summary**

   Different filtering scenarios for non-clear ER-alpha energy-time-position correlated sequences are presented to apply in a nearest future for active correlation technique when DC-280 FLNR, JINR ultra high intense heavy ion beam cyclotron will put into operation.

4. **References**

   [1] Yu.S.Tsyganov //ECHAYA. Vol.45, No.5-6, (2014)1485-1531 / in Russian/
   [2] Yu.S.Tsyganov et al. //Nucl. Instrum. And Meth. In Phys. Res. A-477 (2002)406-409
   [3] Yu.S.Tsyganov // Phys. Of Part. and Nuclei Lett. Vol.12, No.4 (2015) 570-577
   [4] Yu.S.Tsyganov // Phys. Of Part. and Nuclei Lett. Vol.12, No.1 (2015)74-82
   [5] Yu.S.Tsyganov // Phys. Of Part. and Nuclei Lett. 2015. /in print/
   [6] Yu.S.Tsyganov // ECHAYA. 2015 / in print; in Russian/
   [7] Yu.Ts.Oganessian // G. of Phys. G: Part. and Nucl. Phys. 34(2007)R165-R242
   [8] Yu.Ts.Oganessian, Yu.V.Lobanow et al. //Phys. Rev. Lett. vol.83, No.16, (1999)3154-3157