SUPERHEAVY NUCLEI RESEARCH

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Introduction

The attempts of searching for superheavy nuclei with weights up to $A = 10^7$ are well–known.[1,2] Such exotic atomic nuclei can exist as a relic formation appeared at early stages of the Universe formation.[3] Therefore it was quite natural to search superheavy nuclei in such objects as iron and carbon meteorites.[4] The search for such nuclei in transuranium content materials is not unreasonable as well.[5] The backscattering of ^{238}U nuclei was used as the searching tool on the specially prepared targets. For the elastic scattering registration of uranium nuclei the combined $\triangle E$ and transit time technique of nuclear reaction products registration was used.[6] The sensitivity limit of this technique $\sim 10^{-12}$ didn't allow to find out excessive unobservable mass in the form of superheavy nuclei in observable Universe.

One of the major indirect evidence of superheavy nuclei existence is their alpha–decay characteristic. Via the analysis of ratio between the energy of alpha–particle decay and life–time of the parent nucleus it is possible to estimate a parent nucleus charge value.[7] Recent calculations[8] has shown that isotopes in decay chains of the newly discovered superheavy even–even nuclei are characterized by the values of spectroscopic factors

$S_\alpha = 0.2 \ldots 0.5 \times 10^{-2}$. However this value even for nucleus $^{288}114$ — $S_\alpha = 0.13 \times 10^{-2}$ indicates most possibly underestimation of its life–time. The advance in the range of nucleus masses with $A > 270$ is problematic and requires experimental studies of the nature of heavy nuclei formation and analysis of their energy and structural characteristics.

One of the ways to superheavy nuclei forming is fusion reaction of heavy ions $^{48}Ca+^{248}Cm$ and $^{48}Ca+^{244}Pu$ with formation of the highly excited systems $^{288}114$ and $^{296}116$ with excitation energy $E^* \sim 36 \ldots 37$ MeV.[9,10] The decay scheme of these highly excited composite systems allow us to make a conclusion that the stability of superheavy nuclei increases with the number of neutrons in the outer shells. This tendency gives a hope to find out or to synthesize nuclei from the islands of stability.[11] However this method of superheavy elements synthesis has a drawback — high excitation of intermediate compound system and hence the great number of decay channels for such system. In this case large cross–sections for 'cold' intermediate system cannot be expected. Therefore search of another ways to the 'cold' compound nuclei synthesis is a subject for separate investigation. This work presents experimental results of superheavy nuclei search in the samples of laboratory initiated artificial nucleosynthesis.[12]

1. Experiment

Original laboratory installation that was created in Electrodynamics Laboratory 'Proton–21' offered a real opportunity to enhance research in this field. Experiments on this installation allowed to gain self–compressed plasma clots with the density $> 10^{26}$ nucleons/cm^3. The results of X–ray and various spectroscopic studies of the experimental products evidence that intense nuclear processes are going on in the volume of plasma bunch changing the element and isotopic composition of the target.

This paper presents the results of testing experiments with the samples exposed to extremal impact at the 'Proton–21' installation. Coulomb backscattering of alpha–particles was used for this purpose. The experiments were carried out on a classic cyclotron U–120, $E_\alpha = 27.2$ MeV. Schematic diagram of the testing experiment for identification of nuclear reaction products are presented on Fig. 1. Isotopic targets ^{11}B, ^{26}Mg, $^{27}A1$, ^{58}Ni, ^{59}Co as well as $^{63,65}Cu$, ^{197}Au ,$^{206,207,208}Pb$ $h = 60 \ldots 1000$ microgram/cm^2 thick were used for calibration. For energy range measurement of scattered alpha–particles $\triangle E, E$ technique of nuclear reaction products identification (E–detectors with $h = 7 \ldots 17$ microns and

E–detectors with $h = 1000$ microns) was used. Bispectrum data were accumulated by a MEM–3 system using a VLADO spectrometry system. Kinematic area of alpha–particles elastic backscattering exceeding upper boundaries $Pb(\alpha, \alpha)Pb_{g.s.}$ was analyzed. Accumulating screens made of chemically pure copper 500 microns thick were used as targets. Mass–spectroscopy data revealed the presence of the layers (200 . . . 1000 Å thick) of chemical elements that essentially differ from initial target material in the depth $h = 0.05 \ldots 0.07, 4.0 \ldots 8.0$ microns.[13] Alpha–particles with energy $E_\alpha = 27.2$ MeV were used for scanning the near–surface area of accumulating screens to the depth up to 300 microns. Energy loss of alpha–

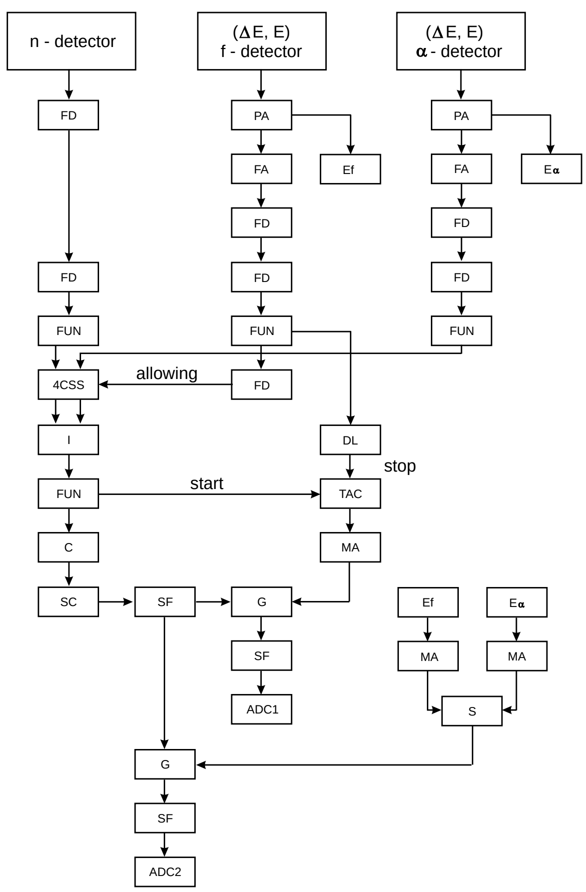

Figure 1. Schematic diagram of the testing experiment for identification of nuclear reaction products.

particles in this layer is equal to 280 keV for copper. Energy dispersion of the 27.2 MeV alpha–particle beam is 270 keV. Investigated kinematic range for elastic backscattered alpha–particles on near–surface area of a target is $E_\alpha = 25.0 \ldots 26.7$ MeV.

Taking into account the alpha–particle current on a target $I = 2 \ldots 4$ nA in the kinematic range of the experiment, background interferences were detected with the cross–sections less than 10^{-14} barn. That interference threshold allows to consider singular counts with cross-sections 10^{-10} barn as statistically significant.

The experiments in the investigated kinematic area revealed statistically significant events that can be related to the processes of elastic scattering on the superheavy nuclei ($A = 310 \ldots 340$), (Fig. 2–4).

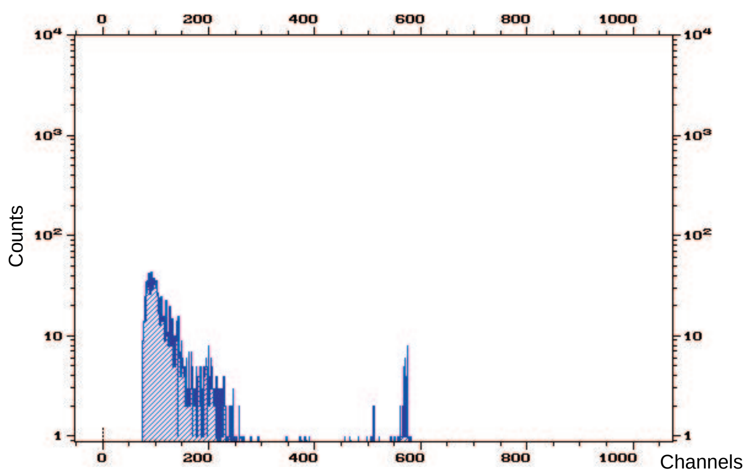

Figure 2. Spectrum of scattered α–particles from ^{206,207,208}Pb(α,α), $\Theta_{l.s.} = 125°$, $E_\alpha = 27.2$ MeV.

2. Experimental data analysis

The energy spectra of alpha–particles scattered on the targets allow us to suppose, taking into account that scale in the investigated kinematic range of masses A is not linear, that the events registered by detectors refer to scattering on superheavy nuclei in the ground state.

It was supposed for the kinematic peak position calculations that nuclei are stable. The order of magnitude of calculated elastic scattering cross-

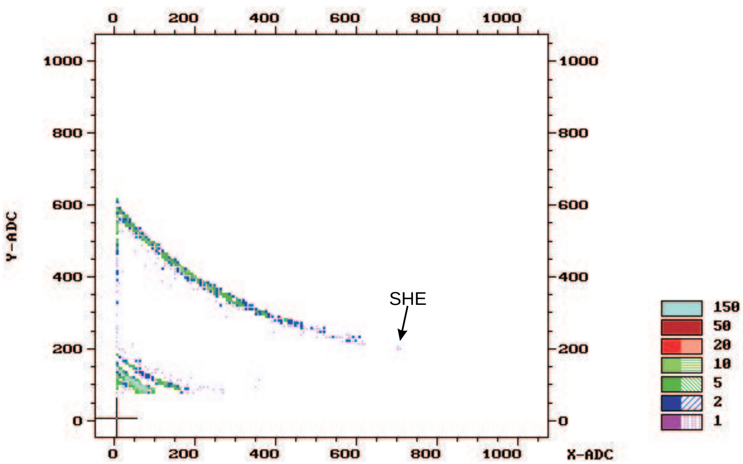

Figure 3. Spectrum of scattered α–particles from superheavy elements (α,α), $\Theta_{l.s.} = 125°$, $E_\alpha = 27.2$ MeV.

sections (25 nb) matches the order of magnitude of experimental data for $E_\alpha = 27.2$ MeV.

We can state that the experimental cross-sections of scattering on $A = 310 \ldots 340$ nuclei have the value $3 \ldots 6$ nb for $\Theta_{l.s.} = 130° - 150°$.

Hence if the stable superheavy nuclei with such masses have the same ratio $A/Z = 2.54$ we can evaluate their charge. The range of possible masses $A = 310 \ldots 340$ and charges $Z = 122 \ldots 131$ was obtained.

3. Summary of results

The experiments of Coulomb backscattering of alpha–particles $E_\alpha = 27.2$ MeV on the targets gained in experiments of laboratory nucleosynthesis revealed statistically significant events that can be related to the processes of elastic scattering on the superheavy nuclei with masses $A = 310 \ldots 340$ and charges $Z = 122 \ldots 131$. The order of magnitude of calculated elastic scattering cross-sections matches the order of magnitude of experimental data.

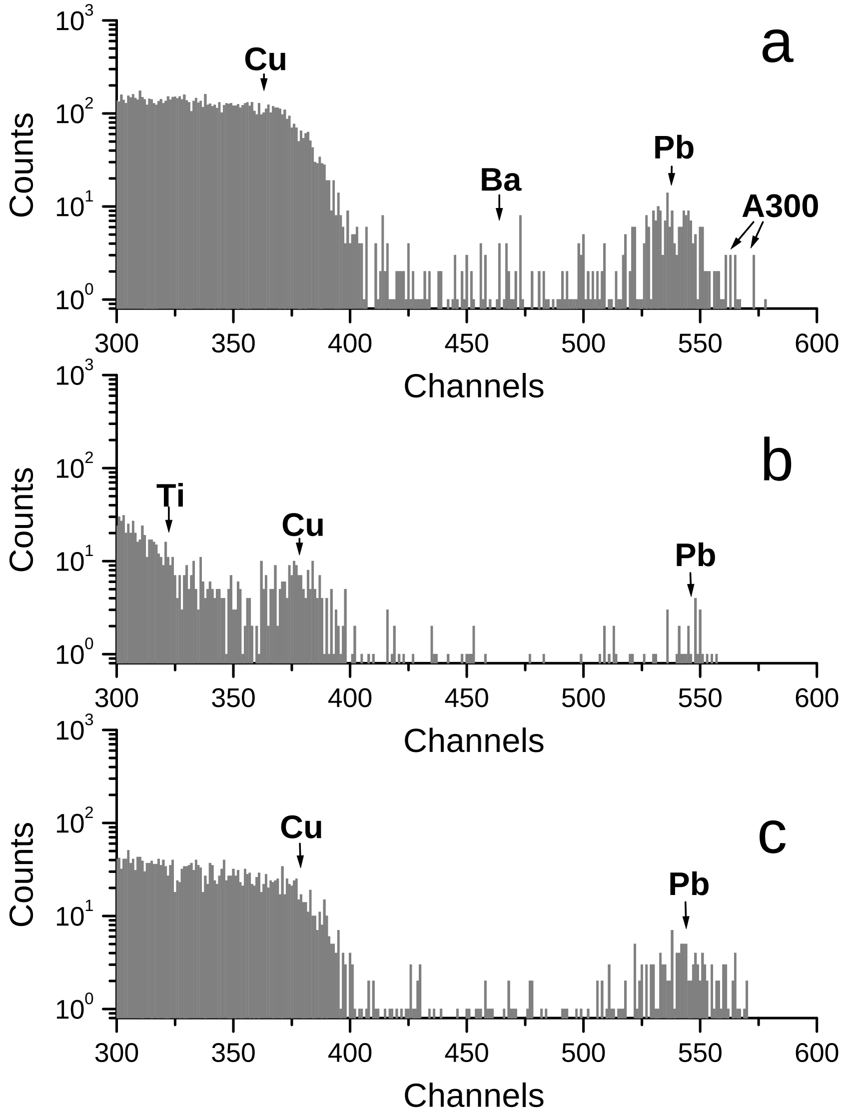

Figure 4. Spectra of scattered α–particles from different samples, $\Theta_{l.s.} = 135°$, $E_\alpha =$ 27.2 MeV.

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