to the focal plane of FMA. In this experiment the highest statistics was obtained for ^{221}Th. Its γ energy spectrum obtained through γ -recoil coincidence, is shown in Fig. 3, in agreement with previous results[7].

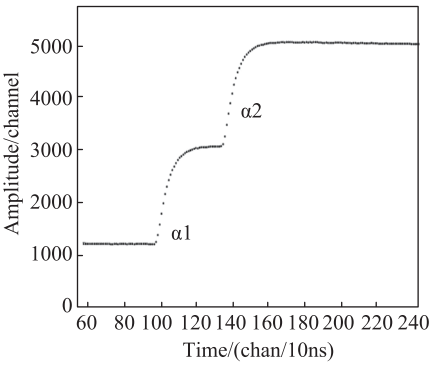

Fig. 1 An example of superposition waveforms.

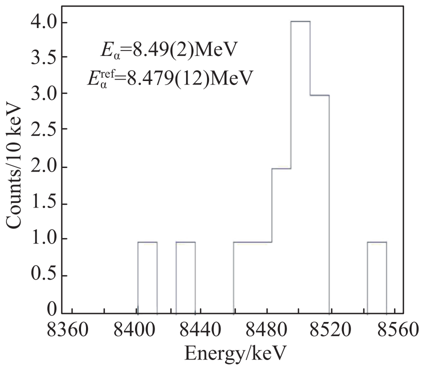

Fig. 2 The α energy spectrum of ^{224}U. The counts of it is only about 20.

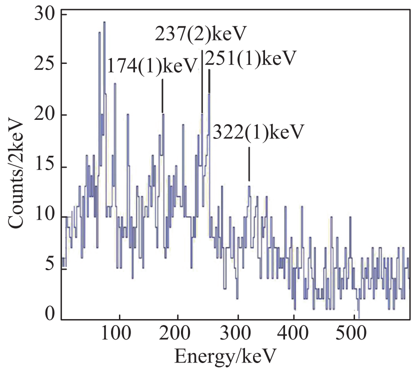

Fig. 3 (color online) The γ energy spectrum of ^{221}Th. The energy values of the strongest γ rays of ^{221}Th are marked in the figure.

We will propose to study ^{224}U again using the ^{48}Ca(^{180}Hf,4n) reaction at 207 MeV on AGFA at ANL, which is to be commissioned in 2017.

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2 - 24 Research Progress of Heavy Ion Reaction Group

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In 2016, the environment of the power supply of RIBLL1 is improved by building a closed space with air condition. It will be good for the magnetic stability which is directly affected by the stability of the power supply. There are 9 experiments, more than 1 165.5 h beam-time, carried out at the RIBLL1. The users are from Peking University, China Institute of Atomic Energy, Shanghai Institute of Applied Physics, National Space Science Center, Institute of High Energy Physics and Institute of Modern Physics. The research topics are as the following, elastic scattering of proton dripline nuclei ^{12}N and ^{13}O, transfer reaction and elastic scattering study of the mirror nuclei ^{10}Be and ^{10}C, measurement of the fusion reaction cross section of ^{16}O+^{40}Ar near coulomb barrier, experimental study of the giant resonance of the neutron-rich isotopes $^{32-34}$Al, experimental study of the analogous Holy state of ^{11}C, study of the linear molecular state of ^{14}C and measurement of the decay of ^{45}Cr and ^{49}Fe, *etc.* Two experimental results, which were performed in 2015, have been published in 2016. One is the revalidation of the isobaric multiplet mass equation at $A = 53$, $T = 3/2$[1]. Another is lifetime measurement of the first excited state in ^{37}S[2].

The different behaviors of the elastic scattering between the neutron halo nucleus ^{11}Be and the proton halo nucleus ^{8}B are investigated using the Continuum Discretized Coupled Channel (CDCC) method[3]. The Coulomb potential and centrifugal potential of the valence nucleon in ^{11}Be and ^{8}B are found to play an important role in the different angular distributions of the elastic scattering differential cross sections. A new measurement of the elastic scattering of ^{7}Be, ^{8}B and ^{9}C isotones also shows the same tendency. It indicates that the effect of breakup reaction channel on the elastic scattering for the proton-rich nuclei can be neglected. The elastic scattering measurement has been done for another proton-rich isotones ^{12}N and ^{13}O and the data analysis is under way. The detector system for the elastic scattering research is also being continuously developed. The effective geometrical efficiency has been improved from 20% to 70%. The readout channels reach 500.

There is a big progress on the analysis of the breakup reaction of ^{9}Li on Pb target. The t + ^{6}He cluster structure is observed experimentally at the excited ^{9}Li with the excited energy of 9.8 MeV by an invariant mass method as shown in Fig. 1. The spin and parity of this resonance state are determined by the angle correlation analysis of the two decay products, t and ^{6}He, and the CDCC calculations. The strength of the monopole transition from the ground state to this excited state is extracted as 5.0 fm^{2}. This is the first experimental evidence of the t + ^{6}He cluster state in excited ^{9}Li which is predicted by Yoshiko Kanada-En'yo *et al.*[4,5]. An advanced and compact array detector is under developing for light charged particles.

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2 - 25 Revisit of Density, Temperature, Symmetry Energy Determination Based on MFM Formalism

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In 1967, Fisher proposed a droplet model of a second-order phase transition to describe the power law behavior of the "fragment" mass distribution around the critical point for a liquid-gas phase transition[1]. Decades later, the Purdue group generated a novel classical droplet model, which was the so-called Modified Fisher Model (MFM), based on the Fisher Model (FM) and introduced it into nuclear physics[2−4]. Taking into account the basic nuclear properties, such as the Coulomb force, pairing effect, proton-neutron two-component mixture, the MFM is capable of describing the general features of the mass and isotopic yields with a minimum number of free parameters[2−4].

In 2014, isotope yields from ^{64}Zn + ^{112}Sn at 40 MeV/u were utilized to extract the density, temperature and symmetry energy of the fragmenting system, based on the modified Fisher model (MFM)[5]. This is one of the series of similar analyses[6−10]. From the pioneering works of Purdue group in Refs. [2−4], the isotope yield with N neutrons and Z protons was expressed as

$$Y(I,A)=Y_0\cdot A^{-\tau}\exp\left[\frac{W(I,A)+\mu_{\rm n}N+\mu_{\rm p}Z}{T}+N\ln\left(\frac{N}{A}\right)+Z\ln\left(\frac{Z}{A}\right)\right]. \tag{1}$$

Here $A=N+Z$ and $I=N-Z$. Following to Refs. [2−4], $W(I,A)$ is given along with the generalized Weiszäcker-Bethe semiclassical mass formula when the mixing entropy is defined along the standard positive definition as

$$S_{\rm mix}(N,Z)=-\left[N\ln\left(\frac{N}{A}\right)+Z\ln\left(\frac{Z}{A}\right)\right], \tag{2}$$

Eq.(1) is rewritten as

$$Y(I,A)=Y_0\cdot A^{-\tau}\exp\left[\frac{W(I,A)+\mu_{\rm n}N+\mu_{\rm p}Z}{T}-S_{\rm mix}(N,Z)\right]. \tag{3}$$

As one can see easily, in the above equation the symmetry energy and the mixing entropy have the same sign. As shown in the appendix, the mixing entropy sign should be opposite. The corrected MFM formula is

$$Y(I,A)=Y_0\cdot A^{-\tau}\exp[\frac{W(I,A)+\mu_{\rm n}N+\mu_{\rm p}Z}{T}+S_{\rm mix}(N,Z)]. \tag{4}$$