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Determination of Density of Nuclear Emulsion Plate by using Range-Energy Relation Calibration Source

Khin Than Tint*

Abstract

The density of nuclear emulsion plate is determined by using the alpha decays of thorium series, which is one of the range- energy relation calibration sources. We picked thorium series in the emulsion plate, Mod#64; Pl# 9, of KEK- E373 experiment. Five alpha decays from ^{228}Th were observed in the decay chain of thorium series. Among the five α particles tracks, the α-particle from ^{212}Po has higher energy than others and α-particle from ^{228}Th, is observed a little distant from others, are used. We measured the position coordinates of the tracks of the α-particle by using microscope system. The range distribution is plotted as the squared length in the focusing direction, Δz^2, versus the squared length in the direction perpendicular to it, $\Delta x^2 + \Delta y^2$. By fitting those data points with a straight line, we obtained the range of α particles as well as the shrinkage factor of nuclear emulsion. The range of α particles from ^{228}Th is 23.358±0.263 µm. Using the average kinetic energy of α particles from ^{228}Th of 5.400 MeV, the density of the emulsion is obtained by using range-energy program which is based on Barka's equation, to be 3.745±0.042 g/cm^3. On the other hand, for α particles from ^{212}Po, kinetic energy 8.7MeV, is obtained as 48.464±0.355 µm, giving the emulsion density of 3.623±0.026 g/cm^3. The density of the nuclear emulsion is determined from the mean of them, 3.684±0.049 g/cm^3.

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စာတမ်းအကျဉ်း

range- energy relation calibration ပြုလုပ်ရာတွင်အသုံးပြုနိုင်သည့် ပင်ရင်းများထဲမှ သိုရီရမ်ယိုယွင်းမှုဖြစ်စဉ်များကို အသုံးပြု၍ နျူကလိယာအီမားလ်ရှင်း ပလိပ်ပြားများ၏သိပ်သည်းခြင်းကို ရှာဖွေသတ်မှတ်ခဲ့ပါသည်။ KEK- E373 experiment ၏ မော်ဂျူးနံပါတ်၆၄၊ ပလိပ်နံပါတ်၉ထဲမှ၊ သိုရီရမ်ယိုယွင်းမှုဖြစ်စဉ်များကို ရွေးချယ်ခဲ့ပါသည်။ သိုရီရမ်ယိုယွင်းမှုဖြစ်စဉတွင် ^{228}Th မှအယ်လ်ဖာယိုယွင်းမှုဖြစ်စဉ် ၅ ခုကိုတွေ့ရပါသည်။ အယ်လ်ဖာယိုယွင်းမှုဖြစ်စဉ် ၅ခုအနက် စွမ်းအင်အများဆုံးရှိသည့် ^{212}Po မှယိုယွင်းလာသော အယ်လ်ဖာနှင့် အခြားအယ်လ်ဖာများနှင့် အနည်းငယ်ဝေးသောနေရာတွင ^{228}Th မယိုယွင်းမှု ဖြစ်ပေါ်နေသောအယ်လ်ဖာများ ကိုအသုံးပြုခဲ့ပါသည်။ အယ်လ်ဖာအမှုန် လမ်းကြောင်းများ ၏ ကိုဩဒိနိတ်များကို မိုက်ခရိုစကုတ်အဖွဲ့အစည်းကို သုံး၍တိုင်းတာခဲ့ပါသည်။ မိုက်ခရိုစကုတ် ရွေ့လျားသည့် စုဆုံလမ်းကြောင်း ၊Δz^2 နှင့်ထောင့်မတ်ကျနေသော ပြင်ည $\Delta x^2 + \Delta y^2$ တို့၏အမှတ်များဆွဲပါသည်။ ထိုအမှတ်များကို မျဉ်းဖြောင့်ဖြင့် fitting လုပ်၍ အယ်လ်ဖာများ ၏ range နှင့် နျူကလိယာအီမားလ်ရှင်း၏ shrinkage factor များကိုရယူခဲ့ပါသည်။ ^{228}Thမှယိုယွင်းလာသော အယ်လ်ဖာအမှုန် ၏ range မှာ 23.358 ± 0.263 µm ဖြစ်ပါသည်။ Barka ၏ ညီမျှခြင်းကို အခြေခံရေးထားသည့် range-energy program အသုံးပြု၍ အရွေ့စွမ်းအင် 5.400MeV အတွက်ရယူခဲ့သော နျူကလိယာအီမားလ်ရှင်း ၏ သိပ်သည်းခြင်း မှာ 3.745±0.042 g/cm^3 ဖြစ်ပါသည်။ တဖက်မှာလည်း အရွေ့စွမ်းအင်8.7MeV ရှိသည့် ^{212}Po အတွက်ရယူခဲ့သော range မှာ 48.464±0.355 µm ဖြစ်ပြီး ၎င်းတို့ကိုသုံး၍ရယူခဲ့သောနျူကလိယာအီမားလ်ရှင်း ၏ သိပ်သည်းခြင်းမှာ 3.623±0.026 g/cm^3 ဖြစ်ပါသည်။ ထိုတန်ဖိုးနှစ်ခု၏ပျမ်းမျှ တန်ဖိုးမှ နျူကလိယာအီမားလ်ရှင်း ၏ သိပ်သည်းခြင်းကို ရယူခဲ့ရာ 3.684±0.049 g/cm^3 ရရှိပါသည်။

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သောချက်စကားလုံးများ။ သိုရီယမ်ယိုယွင်းမှုဖြစ်စဉ်၊ နျူကလီယာအီမားလ်ရှင်း

Introduction

When a charged particle passing through nuclear emulsion, it loses its kinetic energy by Coulomb forces with the negative electrons and positive nuclei that constitute the atoms of that nuclear emulsion. As a result of these interactions, the charge particle loses energy continuously and finally stops after traversing a finite distance, called the range. Therefore, the range depends on the type and energy of the incident particle and the density of the nuclear emulsion. The kinetic energy of charged particles can be deduced by measuring range in nuclear emulsion. Moreover, in nuclear emulsion data analysis, event reconstruction is based on the conservation laws of energy and momentum. And, the masses of hypernuclei are calculated from the energies of their decay daughters. Although the density of the nuclear emulsion plate can be determined by the weight and thickness measured before the beam exposure and after the development of the plate, the accuracy is not sufficient. For these reasons, range-energy relation in nuclear emulsion is quite important to get shrinkage factor and the density of the nuclear emulsion plates. Here, shrinkage factor is defined as the ratio of the thickness of the emulsion plate at the time of beam exposure and that at the time of measurement.

In this paper, how we obtained the density of nuclear emulsion plate by using one of the calibration sources will be presented.

Range-Energy Calibration Sources in Nuclear Emulsion

There are three types of calibration sources in Nuclear Emulsion of E-373 experiment. Monochromatic alpha decay tracks emitted from natural radioisotopes such as Thorium series, Uranium series and $\pi+ \rightarrow \mu^{+} \rightarrow e^{+}$events, existing naturally in nuclear emulsions are used as the calibration sources for range-energy relation. The range of the μ- meson (~ 600μm) from the decay of the pion is a source for calibration. The image of $\pi+ \rightarrow \mu^{+} \rightarrow e^{+}$event in nuclear emulsion of E373 experiment is shown in Fig. 1. The detail descriptions and discussion of other calibration sources, decay chain and photographs of, Thorium and Uranium series are described in a Literature. The photographs of Thorium and Uranium series in nuclear emulsion are described in Fig. 2. and Fig. 3., respectively. The five alpha decay tracks from ^{228}Th are observed in the decay chain of thorium series and four alpha decay tracks from ^{226}Ra can be found in the decay chain of Uranium Series.

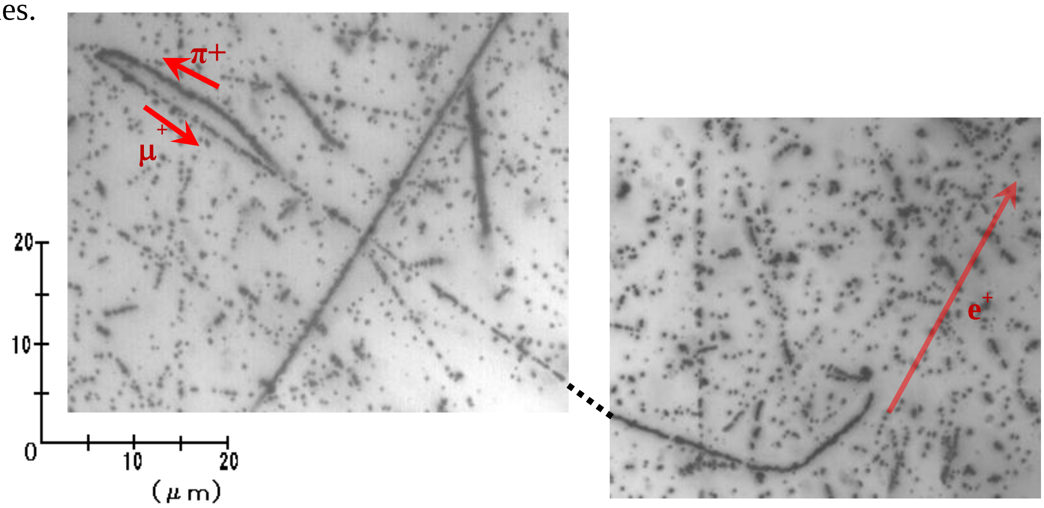

Fig. 1. The image of $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ event in nuclear emulsion of E373 experiment.

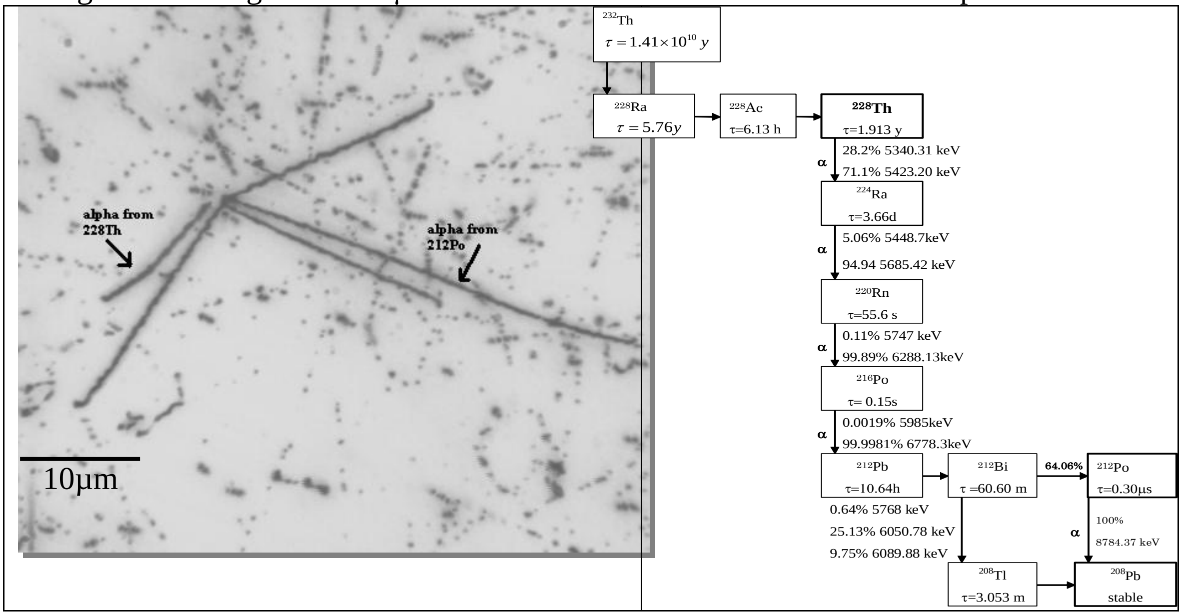

Fig. 2. A photograph of Thorium series in Nuclear Emulsion and decay chain

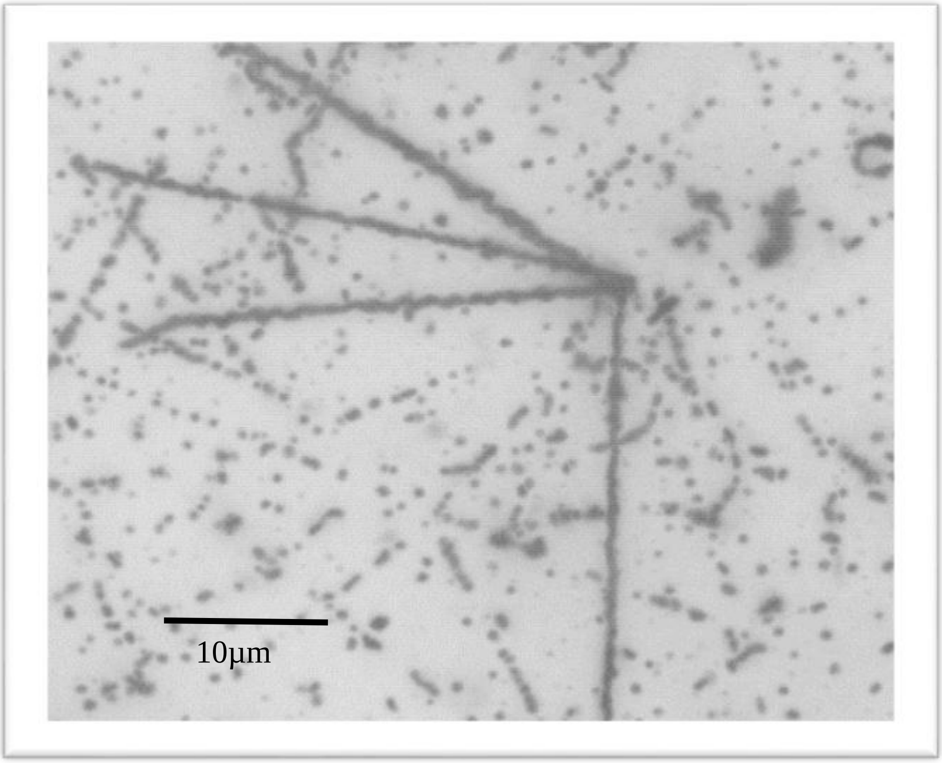

Fig. 3. A photograph of Uranium series in Nuclear Emulsion

Determination of Density of Nuclear Emulsion Plate

The density of the emulsion plate of Mod# 64, Plate#9 is determined by using the calibration source, Thorium decay series, in nuclear emulsion. Firstly, we detected the events in nuclear emulsion with upgrade method, “Overall Scanning” with “Vetex Picker”. Among the various images of the events, we chose the Thorium decay series, 5 track events, as shown in Fig. 2. Secondly, we measured the range from the position coordinates at starting and stopping points of each track in the events in the temperature and huminidy control room. Alpha particles from thorium decay series are mono-energetic of the order of MeV and can therefore be identified by their 3 dimensional ranges in nuclear emulsion. The photographs of the microscope systems for vertex picker and range measurements are shown in Fig. 4. Two alpha particle tracks from the decay of ^{212}Po and ^{228}Th are used in calibration. The reason for why we use those tracks are (i) the α from ^{212}Po has the kinetic energy larger than 8 MeV and has longer range than others and (ii) the emission point of α particles from ^{228}Th is separated from others, because ^{224}Ra can move in its relatively long lifetime of 3.66 days.

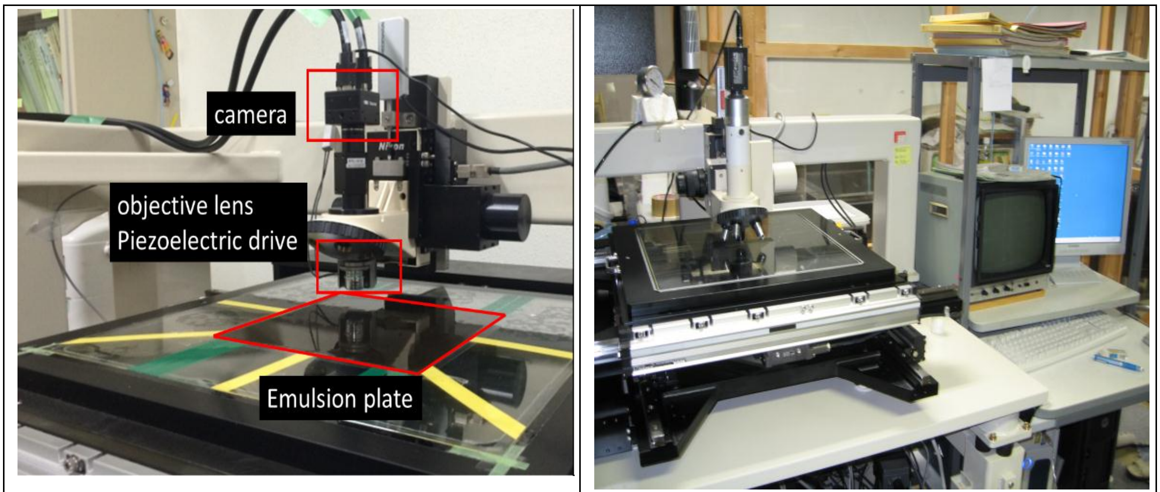

Fig. 4 Microscope systems for vertex picker and range measurement of charge particle tracks

The range distribution of α particles as the scatter plots of Δz^2 versus $\Delta x^2+\Delta y^2$ from the decay of ^{212}Po and ^{228}Th are shown in Fig.5 and Fig. 6, respectively. By fitting those data points with a straight line, straight line equations (y = mx +c), for each track are obtained. In the case of three-dimensional components, measurement of the original ranges in a shrunk emulsion along the Z direction can be obtained by the equation,

$R = \sqrt{\Delta x^2 + \Delta y^2 + (\Delta z^2 \times S^2)}$; where, S is the shrinkage factor. (1)

The above equation (1) can be re-written as Δz^2 is described as a linear function of $(\Delta x^2 + \Delta y^2)$.

$$\Delta z^2 = -\frac{1}{S^2}(\Delta x^2 + \Delta y^2) + \frac{R^2}{S^2} \quad (2)$$

The range R and Shrinkage factor S for each track are obtained by comparing slope and intercept values of fitted results with the above equation (2).

In Fig. 5, the range distribution of 70 straight α tracks emitted from 212 Po are used. The obtained range of α particles from 212 Po, by using Eq. (2) and straight line fitting results, is 48.464±0.355 µm and shrinkage factor of emulsion plate is 2.233±0.016. On the other hand, range distributions of 40 straight α tracks emitted from 228Th are used in Fig. 6. The range of α particles from 228Th is 23.358±0.263 μm and shrinkage factor is 2.333±0.026.

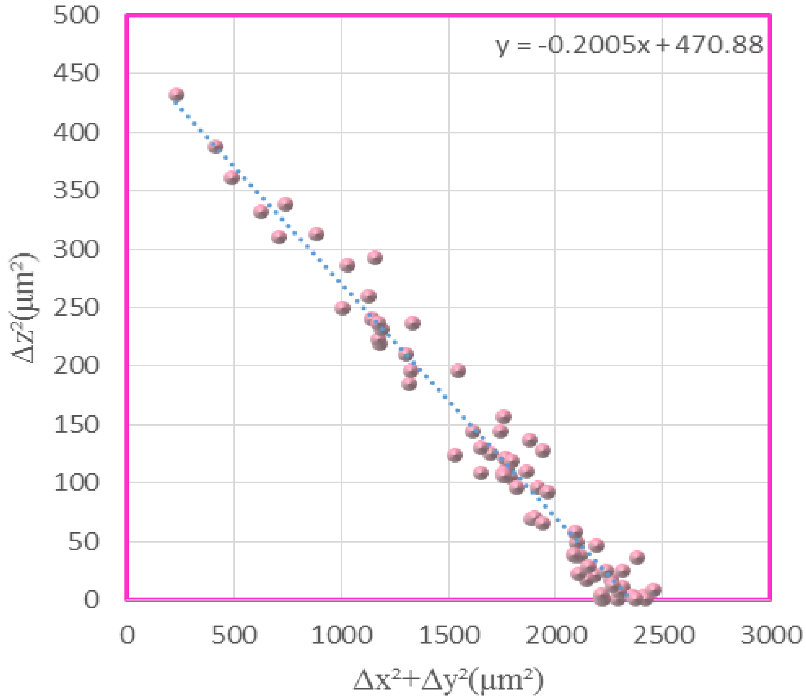

Fig. 5 The range distribution of α particles as the scatter plots of Δz^2 versus $\Delta x^2+\Delta y^2$ from the decay of ^{212}Po.

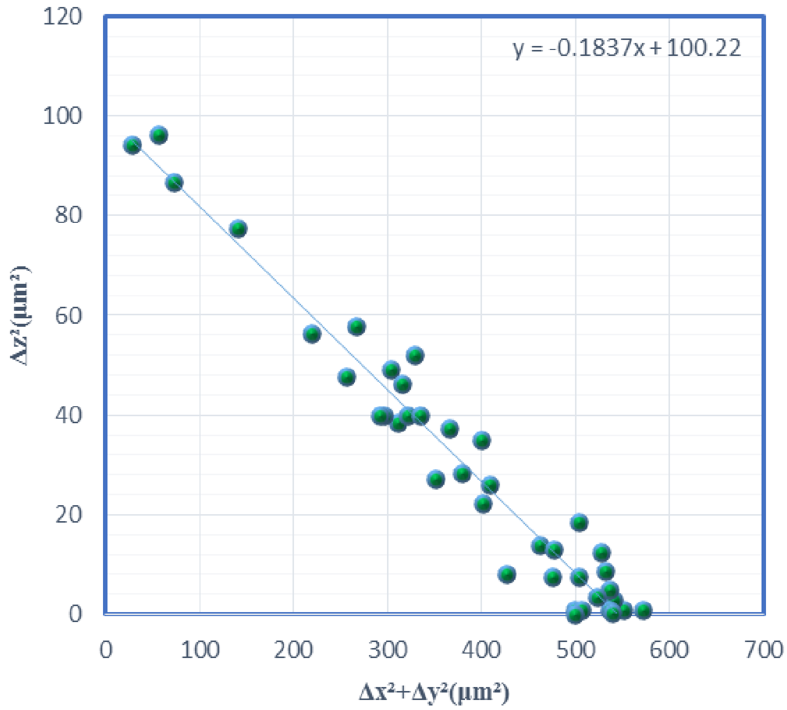

Fig. 6. The range distribution of α particles as the scatter plots of Δz^2 versus $\Delta x^2+\Delta y^2$ from the decay of ^{228Th}.

The average kinetic energy of α particles from ^{212}Po of 8.7MeV, the density of the nuclear emulsion is calculated with the range-energy program written by Prof. K. Nakazawa based on Barkas's equation for the range 48.464±0.355 µm, to be 3.623±0.026 g/cm^3. Similarly, the average kinetic energy of α particles from ^{228}Th of 5.4 MeV and the range 23.358±0.263 µm, the density of the nuclear emulsion plate is 3.745±0.042 g/cm^3. The density of the emulsion gel of the plate #9 of Mod#64 is determined from the mean of the above two values, 3.684±0.049 g/cm^3.

Result and Discussion

The density of nuclear emulsion plate of Mod#64; Pl #9, of E373 experiment is determined by using the range and energy of α particles decay from ^{212}Po and ^{228}Th of Thorium decay series. Firstly, the average range of α particles emitted from ^{212}Po and ^{228}Th and shrinkage factors of nuclear emulsion are obtained from their linear curve fitting of measured coordinate distributions. The obtained range values of α particles decay from ^{212}Po and ^{228}Th are 48.464±0.355 µm and 23.358±0.263 µm, respectively. Secondly, the density values for corresponding α particles decay from ^{212}Po and ^{228}Th are obtained by using the energy values in decay chain and obtained range values. The density values of nuclear emulsion deduced from α particles decay from ^{212}Po and ^{228}Th are 3.623±0.026 g/cm3 and 3.745±0.042 g/cm^3, respectively. Finally, the density of the emulsion plate of Mod#64, Pl#9 is obtained from the average of above two density values, 3.684±0.049 g/cm^3.

Conclusion

Determination of density of nuclear emulsion plate is one of the important factors in the analysis of events in nuclear emulsion. To determine the density of nuclear emulsion, we can use not only Thorium decay series events, but also other calibration sources such as Uranium decay series and $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ event.

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