第28卷 第10期 高能物理与核物理 Vol.28, No.10
2004年10月 HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS Oct., 2004

A Set of Ionization Chamber Telescope Used in Dissipative Heavy Ion Reaction Measurement *

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Abstract In order to identify the charge number Z of the projectile-like fragments emitted from the dissipative heavy ion reactions, a set of ΔE-E telescope has been constructed, which consists of two ionization chambers for ΔE_1 and ΔE_2 in series followed by a position sensitive semiconductor silicon detector to deposit residual energy E. The trajectory of the incident particles is parallel to the direction of the electric field in the ionization chamber. The detector system has a lower energy detection threshold, compact configuration and capability against the disturbance from the electromagnetic wave. The charge resolution of $Z/\Delta Z \approx 30$ of the telescope has been achieved in an experimental measurement of excitation functions of dissipative heavy ion reaction.

Key words ionization chamber, ΔE-E telescope, charge resolution, dissipative heavy ion reaction, projectile-like fragment measurement

The experimental study of dissipative heavy ion collisions requires the identification of the nuclear charge number Z of the reaction products. For this purpose, a gas-filled ionization chamber ΔE-E telescope detection system with longitudinal electric field has been constructed. The basic principle of the ionization chamber[1] is shown in Fig.1.

A charge q is generated at a distance of x from the anode when charged particle passes through the sensitive volume of the chamber. The inducted current on the anode of the ionization chamber is given by,

$$I = \frac{\mathrm{d}q}{\mathrm{d}t} q v_{\mathrm{dr}} / a,$$

where v_{dr} is the drift velocity of the electron, a is the distance between cathode and anode. Then the corresponding voltage signal can be derived as,

$$U(t) = \frac{q(t)}{C} = \frac{1}{C}\int_0^t I(t)\mathrm{d}t = \frac{qx}{Ca},$$

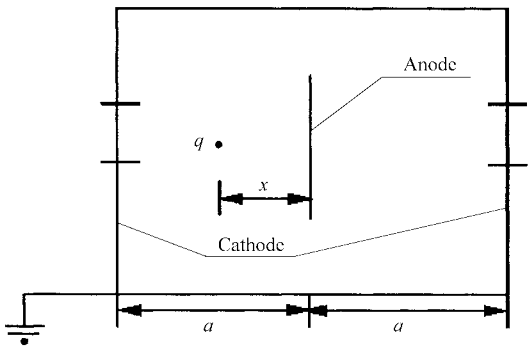

Fig. 1. Principle scheme of the lengthwise electric field ionization chamber.

where C is the capacitance of the chamber. A uniform ionization process of the incident particle in the gas can be assumed, if the energy loss of the charged particle in the chamber is much smaller than the total energy of the particle. Therefore, inducted voltage pulse on the anode of

Received 8 March 2004
* Supported by NSFC (10175083), Major State Basic Research Development Program of China (G2000077400), One Hundred Person Project of Chinese Academy of Sciences and National Key Program for Basic Research, Ministry of Science and Technology(2001CCB01200)
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the chamber is given by:

$$U_m = \frac{N_e}{2C},$$

where N_e is the total number of the electrons generated by a charged particle passing through the sensitive volume of the chamber which is proportional to the total energy loss of the incident particle in the gas. Hence, the extracted output pulse height is also proportional to the energy loss of the particle in the chamber.

Accordingly, a set of ΔE-E ionization chamber telescope system is constructed. The schematical drawing of the telescope is shown in Fig. 2. The container of the telescope is a pyramid-shaped chamber made of brass. It was machined with accuracy by cutting as a whole to ensure a signal against the disturbance from electromagnetic wave and ensure a vacuum in chamber against leakage. The ionization chamber that has a sensitive length of about 60mm, is divided into two sequentially arranged parts of ΔE_1 and ΔE_2 (30mm in length for each). The anodes of ΔE_1 and ΔE_2 are both rectangular empty metallic frames.

A 2μm thick Mylar foil, evaporated with about 30 $\mu g/cm^2$ aluminum on the inner chamber side which is electrically grounded, is acted as the entrance window of the chamber and the cathode of ΔE_1. The ionization chamber ΔE (ΔE_1 and ΔE_2 in series) is followed by a

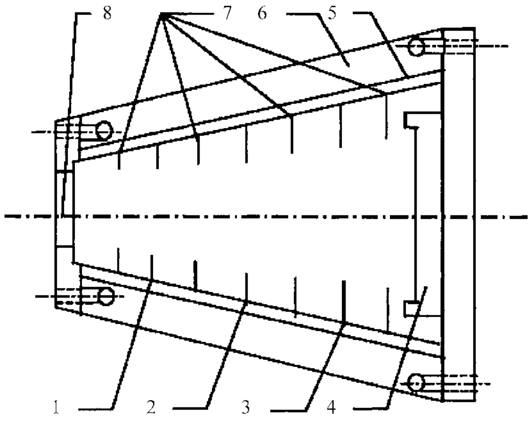

Fig. 2. Configuration of the double-ΔE lengthwise electric field ionization chamber.
1. ΔE_1 anode, 2. ground, 3. ΔE_2 anode, 4. E detector, 5. frame, 6. copper crust, 7. isotonic pole, 8. entrance.

position sensitive surface barrier silicon detector of 300μm in thickness with an active area of 8mm × 45mm to deposit the residual energy E of the incident particle inside the telescope. In order to collect ionized charge produced by the incident particle inside the ionization chamber effectively, two equipotential frame-shape electrodes are placed on both side of the anode to form a strong electric focusing field toward the anode. The simulation of the electric field distribution inside the chamber is shown in Fig. 3.

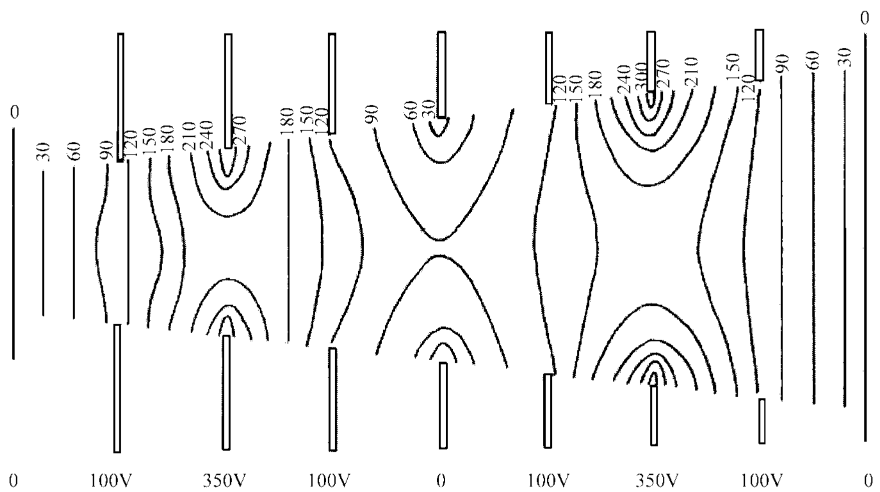

Fig. 3. Electric field distribution inside the ionization chamber.

The performance of the ionization chamber has been tested by using a Th-Th′ Cα source. The chamber was filled with a mixture-gas of 90% argon and 10% methane at a pressure of 200mb in flowing mode. Optimum voltage ratio between the anode and the equipotential frames of the chamber was selected by measuring the voltage plateau curve. The bias voltages at the anode and the equipotential electrodes were 300V and 100V, respectively. The position sensitive silicon detector was cooled by using a semiconductor cooler. The energy signals of ΔE-E and position signal derived from the detector system were amplified and then sent to a multi – channel analyzer. In order to measure the position resolution of the telescope system, a collimator with 16 slits with 0.5mm in width and 3 mm interval between two slits, placed in front of the silicon detector. The test result is that, for the α particles of 8.78MeV and 6.04MeV, the energy resolutions of the ionization chamber ΔE and the silicon detector E are 7% and 0.6%, respectively. The deduced charge resolution $Z/\Delta Z$ of the detection system is about 30. The position resolution of the silicon detector is 0.5 mm.

Recently an experiment of excitation function measurement in dissipative heavy ion collision of $^{19}F + ^{27}Al$ has been carried out at the China Institute of Atomic Energy, Beijing. The $^{19}F^{8+}$ beam was provided by the HI-13 tandem accelerator. The beam energies were varied from 110 to 118.75 MeV in steps of 250keV. The target was a ^{27}Al foil with a thickness of 60μg/cm^2. Four sets of this type of ΔE-E ionization chamber telescope system were installed at $\theta_{lab} = 50°, 30°, -15°$ and $-30°$ in the measurement to identify the charge number Z of the projectile-like fragments. The ionization chamber was filled with a mixture-gas of 90% argon and 10% methane at 100mb pressure in flowing gas mode. The bias voltage of the anode and equipotential electrodes were 300V and 100V, respectively. A pair of permanent magnets were put in front of the chamber entrance window to reduce the strong influence of electrons emitted from the target.

A typical scattering plot of $(\Delta E_1 + \Delta E_2)$-$E$ two dimensional spectrum is given in Fig.4. It is seen that the projectile-like fragments from the $^{19}F + ^{27}Al$ reaction can be separated very well. The distribution of production elements obtained from the Fig.4 is presented in Fig.5. The charge resolution $Z/\Delta Z \approx 30$ of the telescope detection system is deduced. The better charge resolution should be obtained for the higher gas pressure but it will induce higher detection threshold. As an example of the primary data analysis, Fig.6 shows the experimental angular distributions for dissipative product F, Ne and Na elements measured at beam energy 114MeV. The angular distribution

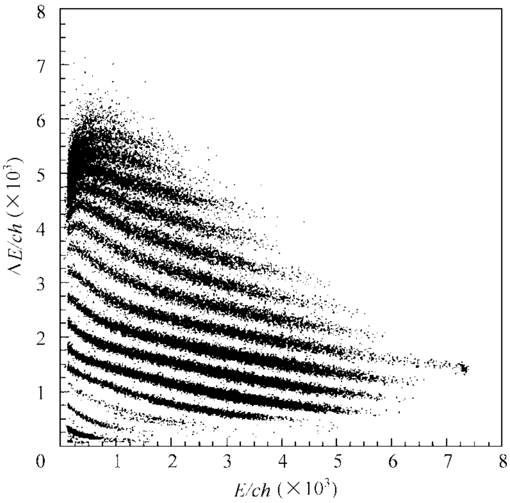

Fig.4. A typical $(\Delta E$-$E)$ scatter-plot obtained at $E_{lab}(^{19}F^{8+}) = 114.25$MeV for $^{19}F + ^{27}Al$ reaction.

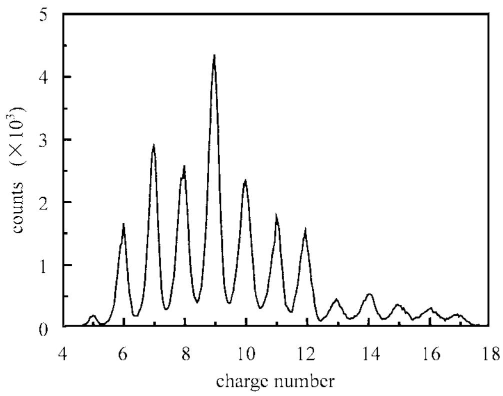

Fig. 5. Charge distribution of the projectile-like fragments from the reaction of $^{19}F + ^{27}Al$ at $E_{lab}(^{19}F^{8+}) = 114.25$MeV and $\theta_{lab} = 15°$.

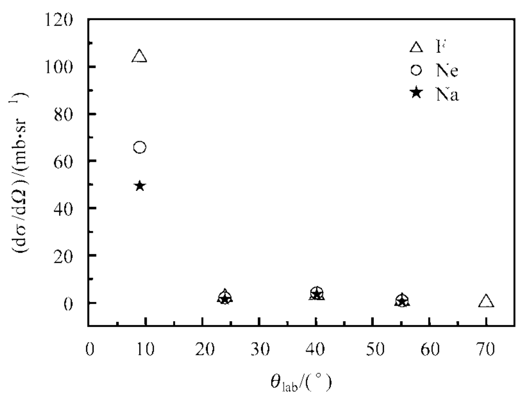

Fig. 6. Angular distributions for different projectile-like fragments measured in the reaction of $^{19}F + ^{27}Al$ at $E_{lab}(^{19}F^{8+}) = 114.00$MeV.

shows a typical feature of dissipative heavy ion reactions, which can be fitted by two different slopes. The ΔE-E telescope system was successfully used in the excitation function measurement of dissipative products from the reaction of $^{19}F + ^{27}Al$.

The advantages of the detection system are lower energy detection threshold and wide dynamical range which allows the detection of the light particles as well as the heavy elements with good resolution. Moreover, the good position resolution makes it to cover a large solid angle with a relative compact detector and the brass outer box makes it with the capability against the disturbance from electromagnetic wave. In fact, this type of ΔE-E ionization chamber telescopes have been successfully and widely used in our experimental measurements of excitation functions of the dissipative heavy ion collisions[2,3].

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一套用于重离子耗散反应测量的电离室望远镜*

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摘要 重离子耗散反应需要鉴别产物的电荷数 Z，为此，研制了一套 ΔE-E 望远镜. ΔE 由两个串接在一起的气体电离室 ΔE_1 和 ΔE_2 组成，位置灵敏硅半导体测量粒子的剩余能量 E. 被探测粒子的轨迹与电离室的电场方向平行. 该望远镜具有很低的能量探测阈，较小的外尺寸和强的抗电磁干扰能力. 重离子耗散反应 $^{19}F + ^{27}Al$ 产物的激发函数实验测量表明，该望远镜的电荷分辨 $Z/\Delta Z$ 约为 30.

关键词 电离室 ΔE-E 望远镜 电荷分辨 重离子耗散反应 类弹碎片测量

2004 - 03 - 08 收稿

* 国家自然科学基金(10175083)，国家重点基础研究发展规划项目(G2000077400)，中国科学院百人计划和科技部重大项目前期研究专项基金(2001CCB01200)资助

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