Performance test of the low-pressure thin window multi-wire chamber *

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Abstract: A flow gas low-pressure multi-wire proportional chamber (LPMWPC) with an active area of 180 mm× 80 mm has been developed for the flying time test of the recoil nuclei on super heavy nuclear experiments. The LPMWPC detector can be operated in single as well as double step operational modes. In the case of double step operational mode with a high gas amplification factor, signals from α-particles reside well above the electronic noise. The gas leakage rate and time resolution obtained from the α ^{239}Pu source are shown and discussed at the condition of 3 mbar Isobutane gas. It was shown that the time resolution was better than 2.9 ns at the best work condition, and the detecting efficiency was larger than 98% at the low energy α particles. So the LPMWPC is fit to measure the flying time in the super heavy nuclear fragments experiment.

Key words: LPMWPC, gas leakage rate, time resolution, detecting efficiency

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1 Introduction

The synthesis of super-heavy nuclei is not only one of the topics at the forefront of the modern nuclear structure theory, but it is also one of the most effective methods of verifying it. During the past several years, the experiments on the synthesis of superheavy elements were mainly based on the heavy nuclear fusion evaporation mechanism [1–3].

The gas-filled recoil separator in HIRFL is used for separation of heavy evaporation residual (EVR) in nuclear reaction. The identification of EVR nuclide is accomplished in a position-sensitive semiconductor detector by detecting a chain of genetically correlated groups of α particles and by detecting fission fragments of the last nuclide. The time-of-flight (TOF) information is used to discriminate the α particle signals from those produced by implanted EVRs and projectile-like and target-like particles, which are occasionally transmitted along the optical axis of the detecting system. In the HIRFL experiments, the time resolution of the TOF detector requires better than 4 ns.

Considering the low kinetic energies of EVRs, PPAC and thin plastic scintillator film detectors maybe not fit their thin film structure. The microchannel plate detectors cannot work in the gas-filled recoil separator. The LPMWPC has many advantages in the fission fragments measurement experiments and in heavy ions experiments. It mainly includes:

1) good time resolution;

2) high efficiency for detecting fission fragments (100%);

3) an extreme insensitivity to relativistic particles (ie, γ ray) and neutron backgrounds;

4) high-rate capability;

5) negligible radiation damage.

Thus the LPMWPC detector can be used to give the time of flight signal used for particle identification [4–7].

2 The structure of the LPMWPC

The sensitive area of the LPMWPC is 180 mm× 80 mm. In future experiments, it just uses the central effective area about 160 mm×60 mm, which can effectively avoid the edge effect. The structure diagram of the detector is shown in Fig. 1. The anode and the cathode of the LPMWPC are made of 20 μm gold-coated tungsten wires with wire pitches at 2 mm and 1 mm, resulting in the different optical transparencies of the anode and cathode wire plan, that are 99% and 98%, respectively. The design of the wire pitch came mainly from reference to working experience and relevant literature.

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Choosing the 2 mm wire pitch of the anode, it could get the balance between the time resolution and detection efficiency. Small pitch wire will decrease the detecting efficiency and require high working voltage, correspondingly, the sparse wire will increase the drift time of electrons resulting in bad time resolution. The dense wire in the cathode could shield the internal electric field, which can make sure the detector is working steady, as the high electric field around the cathode wire may cause a secondary discharge. The anode wire plan is located in the middle of the two cathode wire plan. The distance of the anode to cathode is 7 mm. The wire tension of both the andode and cathode is 60 g. The anode and cathode wire plan are connected into a whole respectively, the signal of the detectors is obtained from the anode wire plan. Ultra thin 0.5 μm mylar film was used as the detector's window.

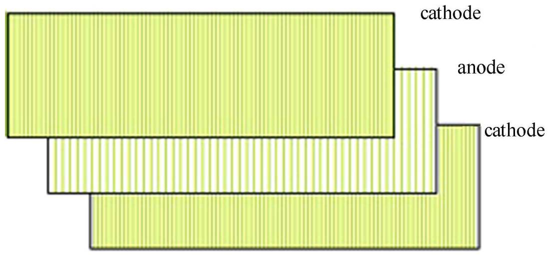

Fig. 1. Structure of the LPMWPC.

3 Gas leakage rate

Due to the poor penetration of the super heavy recoil nuclei, we choose the very thin mylar film as the detector's window in order to improve the detection efficiency. However, this will increase the gas leakage rate of the detector and the risk of damage to the detection system's vacuum environment. Therefore, the detector's overall gas leakage rate is a very important parameter.

As the permeability and the inhomogeneity of the film itself, and the damage in the process of unfolding and flattening it to make the windows, it is necessary to inspect the gas leakage rate of each window before assembly to pick out the qualified windows. In the actual test, only about 50% of the detector windows we produced could reach the requirements. Next, we tested the total leakage rate of the detector after assembly. The leakage rate is measured under atmospheric pressure. We filled air into the LPMWPC to keep its pressure higher than outside (4.57–3.28 mbar). It is larger than its required 2 mbar in the experiment. The pressure decreased rapidly in the beginning few minutes. After three minutes of the duration (3.88 mbar), the pressure declined linearly. The gas leakage rate is about 0.05 mbar/min (Fig. 2). In the experiment, we chose a flow gas model, the gas leakage is safe enough to keep the vacuum environment in the outside of the detector and to maintain the normal operation of the detector.

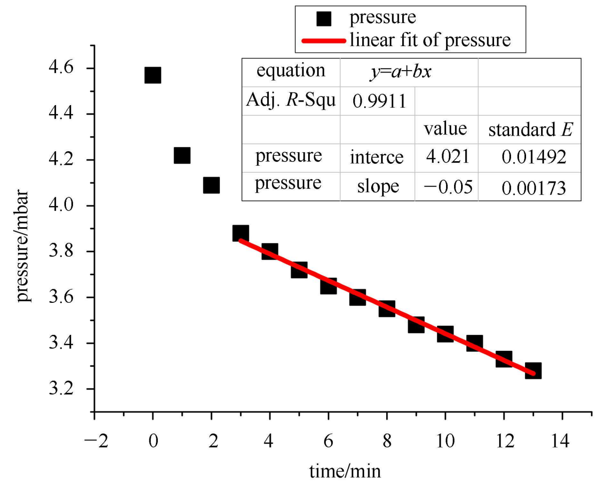

Fig. 2. Gas leakage rate of the LPMWPC is about 0.05 mbar/min when the pressure ranges from 3.88 mbar to 3.28 mbar.

4 Time resolution

The time resolution measurement system (Fig. 3) was composed of ^{239}Pu α source, LPMWPC, plastic scintillators and the electronics. The detectors were placed in a vacuum target chamber and the pressure in the chamber was lower than 1.2×10^{-2} mbar. The LPMWPC was filled with Isobutane and the gas pressure maintained at 2 mbar. The size of the plastic scintillator is 50 mm×50 mm; the distance between the LPMWPC and the plastic scintillator is 100 mm, as the constraints of the vacuum chamber size.

The time resolution in that experiment is mainly influenced by the working voltage of the detectors. To get the best time resolution, we changed the bias voltage on the anode and cathode. In the proper working voltage, which can make sure the detector works normally, the relationship of the working voltage and the time resolution (σ without correction) is shown in Table 1. Choosing the working bias voltage 490 V at the anode and −100 V at the cathode could get the best result.

Table 1. Relationship of voltage and time resolution (σ without correction).

anode/V	cathode/−V	σ (0.1 ns without correction)
507	10	51.4
512	70	37.28
490	100	18.7
460	100	21.42
440	100	26.91
410	125	26.47
380	150	27.62
346	200	44.6

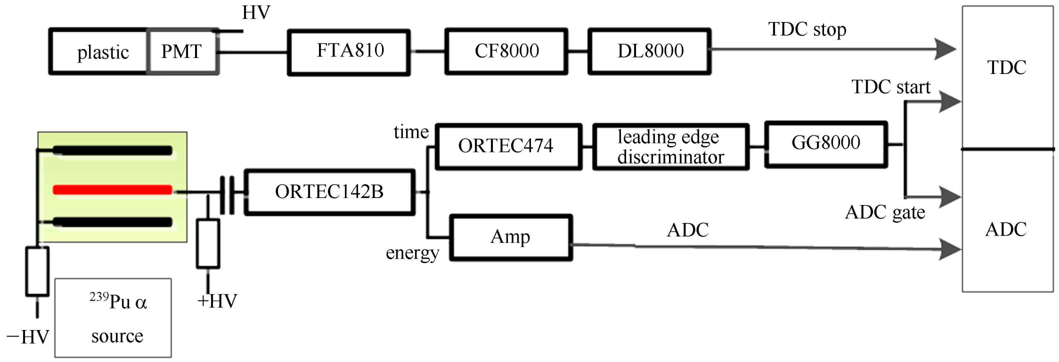

Fig. 3. The time resolution measurement system.

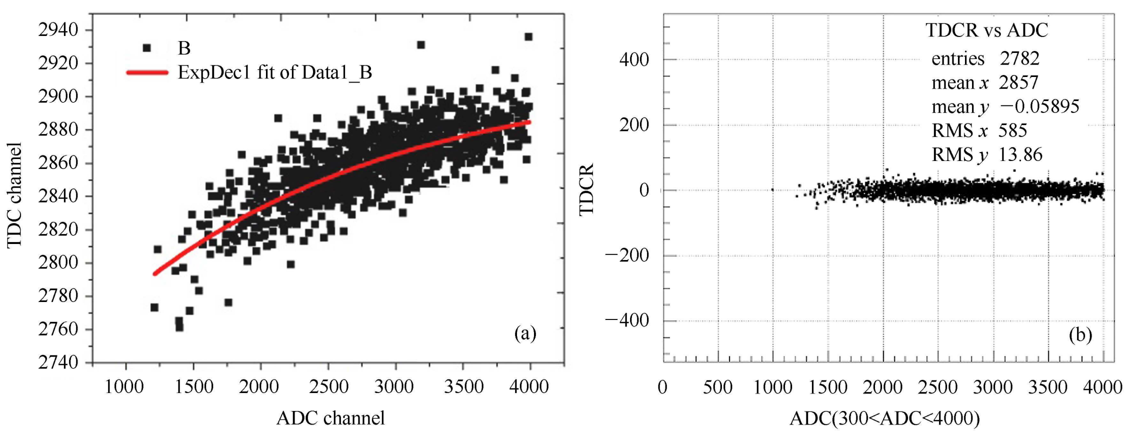

Fig. 4. The relationship of the time-amplitude.

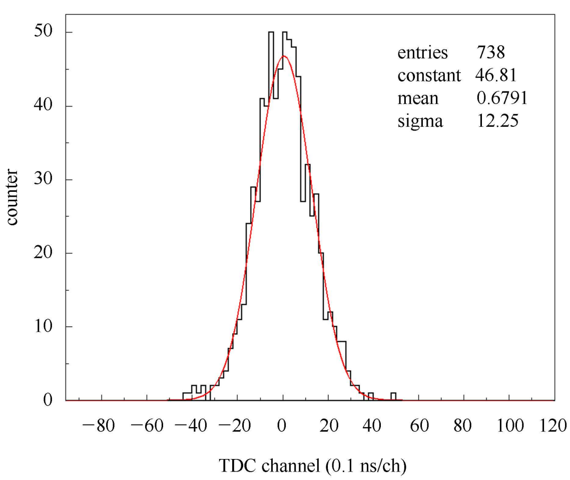

Fig. 5. The time resolution of the LPMWPC.

The LPMWPC anode signal works as the TDC start signal after being amplified by the preamplifier (ORTEC 142B) and the main amplifier (ORTEC 474). The discriminator latch was a leading edge discriminator (Philips 7106). The energy signal of the preamplifier was recorded in ADC. The PMT signal of the plastic scintillator provided the TDC stop signal.

The time resolution of LPMWPC is 4.3 ns (FWHM) without correction. The time resolution is influenced by the amplitude of the LPMWPC anode signal as the leading edge discriminator (Fig. 4(b)). The relationship of the time and amplitude can be described by the following formula [8]:

$$\mathrm{TDC} = -a\times \mathrm{e}^{-\frac{\mathrm{ADC}}{c}}+b. \tag{1}$$

a, b, c are fitting parameters. a=236, b=2906, c=1697.

The right part of Fig. 4 shows that after correction, the time and amplitude are independent of each other. At that time, the time resolution is 2.9 ns (FWHM) (Fig. 5).

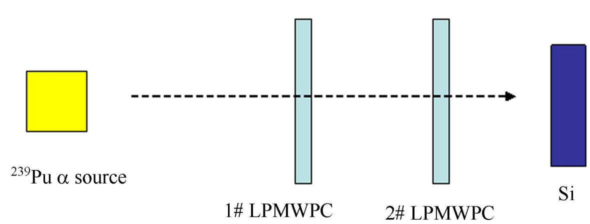

Fig. 6. The detecting efficiency of the LPMWPC.

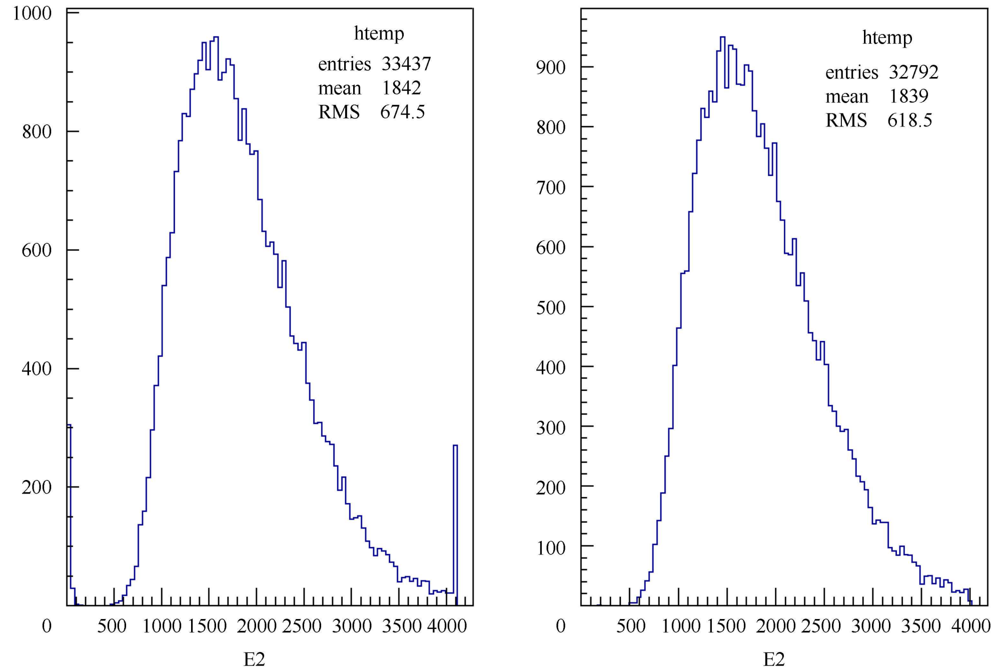

Fig. 7. The coincidence counts of n_{13} and n_{123}.

5 Detecting efficiency

To test the detecting efficiency of the LPMWPC, we designed the test system, as shown in Fig. 6. The test condition of the LPMWPC is the same as the previous experiment. To remove the influence of the γ ray in the radioactive sources, we use a square silicon to replace the plastic scintillator. The 2# LPMWPC (s_2) was placed in the middle of 1# LPMWPC (s_1) and a large silicon detector (s_3), the α source, at one side. The sensitive area of the silicon is 58 mm×58 mm. When an α particle passed through the s_1 and s_3, it must pass the s_2. If the coincidence count of s_1 and s_3 is N_{13}, the coincidence count of s_1, s_2 and s_3 is N_{123}, then the detecting efficiency of s_2 is $\eta = N_{123}/N_{13}$. The coincidence counts are shown in Fig. 7. The detecting efficiency of 2# LPMWPC is better than 98% in this test (N_{123}=32792, N_{13}=33437).

6 Conclusion

The test results show that the gas leakage rate of the LPMWPC detector was better than 0.05 mbar/min in 3 mbar Isobutane gas, the time resolution was 2.9 ns and the detecting efficiency was greater than 98% with the ^{239}Pu α source. So it is suitable for the measurement the flying time of the recoil nuclei in the experiment on the synthesis of superheavy nuclei.

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