The development of resistive plate chamber for LEPS2 experiment

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(Dated: March 22, 2019)

We have developed a resistive plate chamber (RPC) with 2 m long read-out strips for LEPS2 experiment. This RPC is used as a time-of-flight (ToF) detector for charged particles identification with high time resolution. In order to separate particles precisely, the time resolution (σ) below 75 ps is needed. Our RPC satisfied this requirements and achieved 65 ps resolution with 99% efficiency. In this report, we present the performance study and the results.

I. LEPS2 experiment

The LEPS2 experiment aims to study hadron physics via measurements of photo-production process at SPring-8/BL31LEP beamline. This beamline provides a few GeV polarized photon beam with the backward Compton scattering. Irradiating ultraviolet laser to electrons circulating in the SPring-8 storage ring with 8-GeV energy, and we obtain the high energy photon (up to 2.9 GeV) as a beam. This beam is injected into the target and the produced charged particles are detected by LEPS2 solenoid spectrometer. The LEPS2 spectrometer consists of a large solenoid magnet whose inner bore size is 2.22 m long and 2.96 m in a diameter, drift chambers (DCs), a time production chamber (TPC), aerogel Cherenkov counters (ACs), barrel electromagnet calorimeter (Barrel γ), and barrel RPCs, as shown in Fig. 1. DC and TPC detect the trajectory of the scattered charged particles, which is curved in the magnetic field. We can determine the momenta of the particles from the curvature. Barrel γ detects the photons that are generated from hadron decays. AC and barrel RPCs are used to identify the charged particles. In particular, using barrel RPCs, we distinguish between pions, kaons and protons. We obtain the velocity of scattered particles from the time-of-flight (ToF) measured with barrel RPCs. We obtain the mass of the charged particles from their momentum and velocity. This method is called as ToF method.

It is noted that our challenge is to achieve high resolution with long strips. In order to distinguish between pions and kaons with 3 sigma separation power, we require the LEPS2 RPCs to have the time resolution better than 75 ps (σ). We designed the chamber with 2 m long read-out strips in order to cover a scattering angle region between 30-120 degrees.

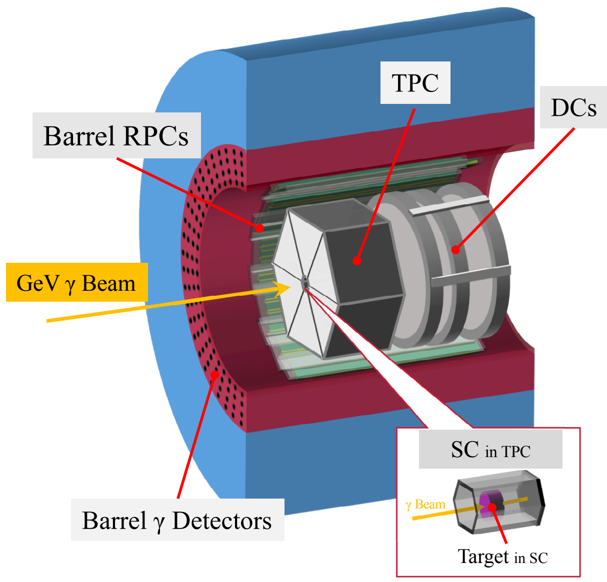

FIG. 1. Schematic view of LEPS2 solenoid spectrometer. The inner bore is 2.96 m in diameter

II. Operating principle and design of barrel RPC

The RPC is a gaseous chamber to detect charged particles. This detector provides sub-100 ps time resolution with capability of operating stably in magnetic fields. The RPC consists of high resistive plates (e.g glasses), narrow gas gaps, electrodes applied HV and insulator boards printed readout strips (e.g see Fig. 2 (left and middle)). Charged particles penetrating a RPC ionize the gas between gas gaps. Since high electric field is generated between electrodes, the electrons produced by ionization accelerate enough to cause other ionizations. The electrons liberated in these secondary ionizations also accelerate to produce more electrons. This results in increasing the number of electrons rapidly like an avalanche (this phenomenon is called as avalanche multiplication). The drifting and increasing electron swarm induces the signal on the read-out strip. Detecting the electrical signal which transmitted on the strip, we can access when charged particles hit.

In particular, multigaps structure provides better time resolution and higher efficiency. We built the barrel RPC in this construction scheme. The schematic of this chamber is shown in Fig. 2 (left and middle) and the picture is shown in Fig. 2 (right). The RPC has double stacks and 5 gaps per one stack, and is almost same as a chamber in BGOegg[1]. The two inner carbon electrode are suppled to positive HV and the two outer are to negative HV. Therefore, the electron swarm drifts in the direction to the anode strip at the center. RPC has 12 strips and the size of the strip is 2.55×200 cm^2. Since it is difficult to handle 2 m long thin glasses and the associated printed circuit boards (PCBs) used for patterning the read-out strips, we joined two 1 m pieces of each. The strips are connected by soldering at the junction with short copper tape. The gas mixture consisted of 90% of R134a, 5% of butane and 5% of SF_6.

Preamp boards at both ends of strips amplify the induced signal by the gain of about 100. We use two cascaded fast amplifier chips on this board (the detail is described in [2]).

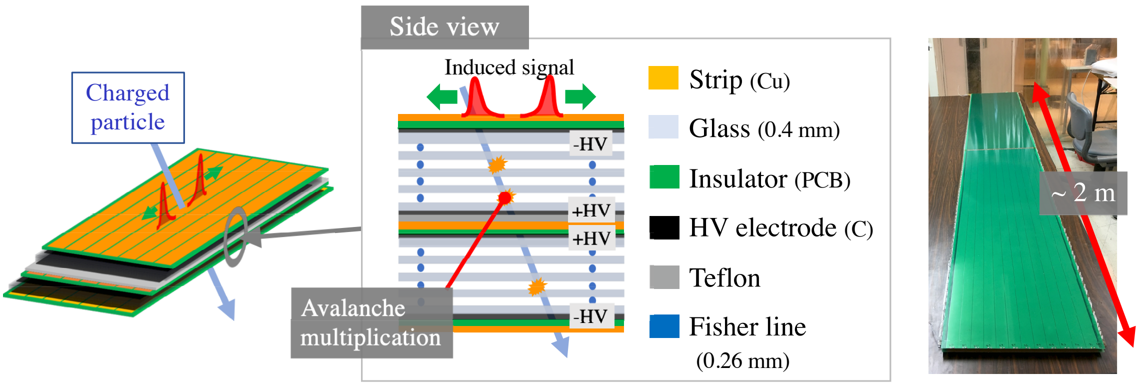

FIG. 2. Left figure show the schematic of the layer structure and middle one the schematics of the cross section for a barrel RPC. The layer stack consisting of gas gaps and glasses is in gas tight chassis. Right is the picture of the stack that will be installed in a gas tight chassis.

III. Performance study

A. Experimental setup

We have evaluated the efficiency and the time resolution of the barrel RPC. The test was carried out at SPring-8/BL31LEP beamline. Figure 3 shows the experimental setup. A few GeV gamma beam is irradiated to a Pb converter and e^+e^- pairs are created. Using a dipole magnet, we selected electrons and injected into RPC. We placed two crossed scintillators upstream and downstream of RPC. We used the coincidence signal of these scintillators as a trigger for data taking. The size of this trigger region (overlap region of crossed scintillators) was 1.5×1 cm^2. By moving the RPC with the trigger scintillators position fixed, we obtained the beam hit position dependence. The trigger rate was below 100 cps/cm^2 while data taking. We applied 13 kV HV to the barrel RPC, which is optimized value from HV scan test.

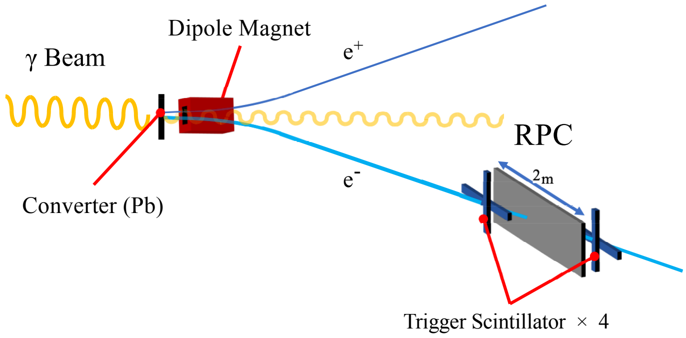

FIG. 3. The experimental setup of time resolution test.

B. Analysis

We measured time difference between RPC signal and RF signal produced synchronously with the electron bunches in the SPring-8 storage ring. The RF signal was referred as the start time of ToF. The electrons produced at Pb converter are high energy upto a few GeV, and their velocities can be regarded as the speed of light. Since flight pass of the electron was almost same in every event, the time difference was almost constant except for uncertainties from time jitter of RF and time resolution of the RPC. Since the jitter of RF is less than 20 ps, we can consider that the uncertainty of the time difference was dominated by the resolution of RPC (the typical resolution of RPC is over 50 ps). Thus, We evaluated a time resolution as a r.m.s. of a Gaussian fitted to the histogram of time difference. It is noted that we corrected the time walk effect using charge information of the RPC signal. Figure 4 shows a typical histogram of the time difference distribution after the correction and the Gaussian fit result (the red curve).

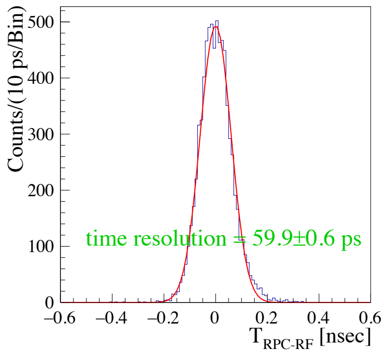

FIG. 4. Histogram of time difference between RF signal and RPC signal.

C. Results

Figure 5 shows the hit position dependence of the time resolution. The horizontal axis represents the hit position along the strip, and the origin of the horizontal axis refers to the center of the strip. The vertical axis shows the time resolution. One can see that the time resolution is about 65 ps except for near 0 cm. This deterioration is due to jointing of glasses and strips. We will omit the data around the region while physics data taking. One also can see the deterioration around the strip end. This is likely to be due to the signal reflection effect. We also evaluated the efficiency of this chamber and confirmed it is over than 99%. This chamber satisfies the requirements of LEPS2 experiment.

IV. Summary

We contracted RPCs with 2 m read-out strips for LEPS2 experiment. This chamber provides excellent the time resolution about 65 ps with 99% efficiency and meets the requirement of LEPS2 experiment. The detail of this report

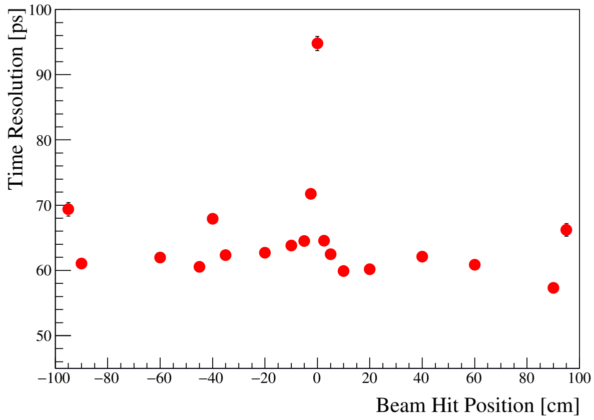

FIG. 5. The beam hit position dependence of the time resolution.

is shown in [3]. Now, we are proceeding mass production. We will study the particle identification performance with the momentum information obtained using TPC in 2019.

[1] N. Tomida *et al.*, Nucl. Instrum. Meth. A **766**, 283 (2014).
[2] N. Tomida *et al.*, JINST **9**, C10008 (2014).
[3] K. Watanabe *et al.*, Nucl. Instrum. Meth. A **925**, 188 (2019).