High time resolution resistive plate chambers for the LEPS2 experiment

The construction of LEPS2, a new GeV photon beamline, has started at **BL31LEP**. LEPS2 will be used to study subnuclear physics with photoproduction of baryons and mesons from nuclei. A multi-GeV photon beam is produced by backward Compton scattering of laser photons with 8 GeV electrons in the SPring-8 storage ring. The LEPS experiment at BL33LEP has produced various data concerning photo-productions of pentaquarks and ϕ-mesons using laser-electron photons [1,2]. However, the acceptance of LEPS detectors is limited to a forward angle, and a spectrometer covering a full solid angle is long awaited. Figure 1 shows the schematic drawing of the LEPS2 spectrometer. This device consists of a solenoid magnet and covers almost 4π sr. The solenoid magnet was that used for the AGS E787/E949 experiment at the Brookhaven National Laboratory in the U.S. It was transported to SPring-8 in 2012. Detectors that will be used to identify particles and to measure their momenta are now under development. Trackers, particle identification detectors and calorimeters will be placed in the magnet. Particle identification will be performed with time-of-flight (TOF) detectors and aerogel Cherenkov (AC) counters. The TOF detectors will be installed in a barrel region with a radius of 0.9 m and a depth of 2.0 m. The flight length from the target to the TOF detectors will range from 0.9 m to 1.7 m. In order to separate kaons from pions up to 1.1 GeV/c via a TOF measurement with 3σ accuracy, a high time resolution of up to 50 ps is required. No experimental group has achieved such a good time resolution with large-area (~10 m^2) coverage; thus, this is a challenging task.

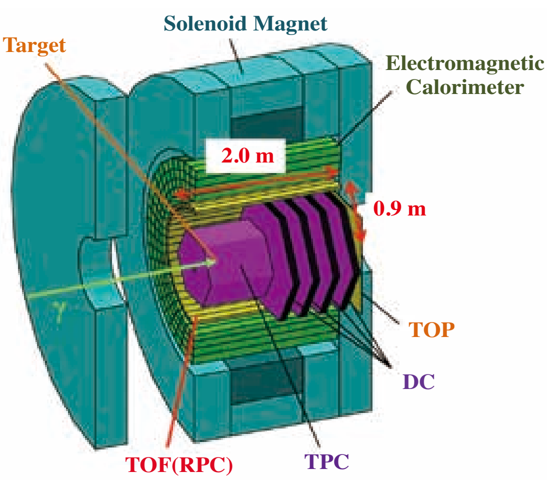

Fig. 1. Schematic drawing of the LEPS2 detector. RPCs cover the barrel region (painted yellow).

The start timing of TOF measurements can be determined with a 15 ps resolution using the RF signal from SPring-8 accelerators. We chose resistive plate chambers (RPCs) for the stop counters of TOF measurements. RPCs are gas detectors made of high-resistivity glasses. A typical structure of the detectors is shown in Fig. 2. When a charged particle passes an RPC, gas is ionized and avalanches occur in the gas gap. Avalanches induce signals on the readout strips. Because of the thin gas gaps, the timing fluctuation of avalanches is small and RPCs can achieve an excellent time resolution on the order of 50 ps. RPCs are employed in many experiments as TOF detectors and used with 70–100 ps resolution [3]. Some prototype RPCs achieved better resolution and the world's best RPC achieved a time resolution of 20 ps including the jitter of front-end electronics [4]. In general, RPCs have better time resolutions with an increase in the number of gaps and a reduction in the area of readout strips. The many RPCs used in high-energy experiments employed small (10 – 20 cm^2) readout strips. However, if the readout strip is small, the number of readout channels becomes large. In order to reduce the readout circuit cost, we should reduce the number of readout channels to less than 2000 in the LEPS2 experiment. This indicates that a readout strip read by one channel should be larger than 50 cm^2. Achieving good time resolutions with such a large readout strip is also a difficult challenge.

We have developed many prototype RPCs and performed beam tests at BL33LEP. The setup of the beam test is shown in Fig. 3. Laser-electron photons were irradiated to a lead target and electron-positron pairs were produced via pair-creation. Electrons were bent with a dipole magnet and passed through the RPCs. The stop timing of TOF was measured with

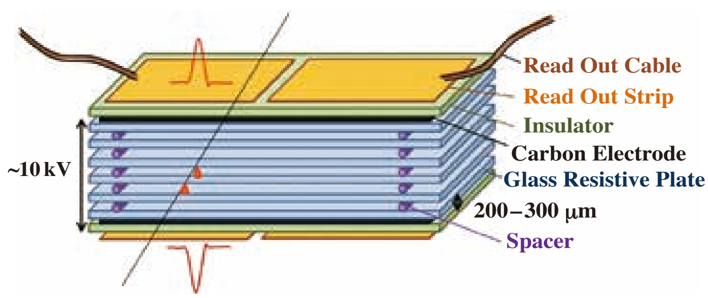

Fig. 2. Schematic drawing of an RPC. A high voltage of about 10 kV/mm is applied to the gas gaps.

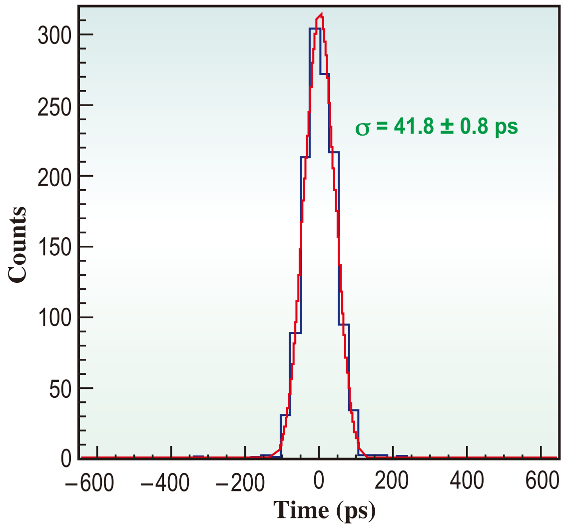

Fig. 4. Time distribution of the 24-gap RPC. The RPC achieved a time resolution of 40 ps.

the RPCs. On the other hand, the start timing was derived from the RF signal. Since both electrons in the storage ring and laser-electron photons fly at the same (light) speed, the time distribution of electrons in the storage ring is conserved in the laser-electron photons at the target position. Thus, the ambiguity of the timing of pair-creation at the target is due only to the bunch width. Owing to the small electron bunch width in the SPring-8 storage ring (~15 ps) and very precise RF signal (<< 10 ps), we can determine the start timing with very good resolution of ~15 ps.

We started with small (8 cm^2) readout strips and examined general features of the RPCs [5]. By increasing the number of gas gaps to 24, we achieved the best resolution of 40 ps including the jitter of front-end electronics (Fig. 4). However, on increasing the readout strip area, the time resolutions became extremely low. The resolution of a 7.4 cm × 10 cm strip (1600 ch at LEPS2) was 150 ps. This was because signals of the large readout strip consist of many signals with different propagation pathways. Then, we attempted to use long [2.5 cm × 40 cm (2000 ch at LEPS2) and 2.5 cm × 100 cm (800 ch at LEPS2)] double-ended strips. With both kinds of strips a 60 ps time resolution was achieved. This was one of the highest resolutions of large-readout-strip RPCs in the world. We found that long strips are suited for high time resolution RPCs. We also examined the position dependence of time resolution and confirmed that there is no big dependence. Long-strips RPCs achieved time resolution of 60 ps even in the gap between strips.

Although the time resolutions of long strip RPCs are slightly lower than the requirement of LEPS2, their performance almost satisfies the requirements of LEPS2. The time resolutions include about 40 ps jitter of front-end electronics and can be improved if we can develop better electronics. We are now developing such electronics and plan to have a beam test at BL33LEP. RPCs will be installed partially at BL31LEP in 2013 and we will start physics experiments.

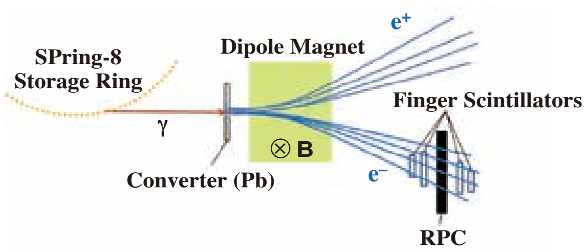

Fig. 3. Experimental setup of beam test at BL33LEP. Gamma rays are converted to electron-positron pairs. Electrons are bent with a dipole magnet and hit the RPC.

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