Resistive Plate Chamber (RPC) for BGOegg Experiment†

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We have developed and installed a time-of-flight system to measure the energy of charged particles, especially protons, for BGOegg experiment. The design of the chamber was based on the RPC chamber for LEPS2 experiment, which we have already reported previously in ref.[1)].

BGOegg experiment using LEPS2 beamline to study hadron photoproductions is currently under operation at SPring-8 (**S**uper **P**hoton **ring**-**8** GeV). The main detector is the BGOegg calorimeter which made from 1320 $Bi_4Ge_3O_{12}$ crystals assembled in the shape of an egg (fig. 1). The BGOegg calorimeter can detect high-energy gamma ray coming out from the target in an open angle of 24 to 144 degrees; an energy resolution of 1.3 % at 1 GeV gamma energy was achieved and previously reported at ref [2)].

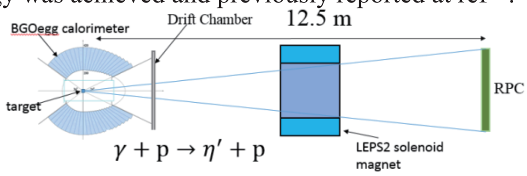

Figure 1: setup of the BGOegg experiment

The RPC is placed 12.5 m downstream from the target, and covers an open-angle of 7^o in the horizontal and 4^o in the vertical. In BGOegg experiment, we are measuring the η' mass modification to study the $U_A(1)$ anomaly problem using a nuclear target with the BGOegg detector system and the LEPS2 high-intensity photon beam. We are looking for the presence of the η' meson in its decay to $\gamma\gamma$, $\pi^0\pi^0\eta$ in the nuclear medium. In addition, the momentum of a forwardly recoiled proton in the A(γ,η') reaction will be measured by the RPC. We use the RF signal as the start signal and the RPC signal as the stop signal, the time resolution must include the contribution of all uncertainty sources such as the amplifier, discriminator, RPC, TDC and the time reference RF.

$$\sigma_{ToF}^2 = \sigma_{RF}^2 + \sigma_{Amp}^2 + \sigma_{Dis}^2 + \sigma_{TDC}^2 + \sigma_{cable}^2 + \sigma_{RPC}^2$$

For the timing measurements, CAEN V1290A TDC modules were used. The resolution of the RF signal is about 4 ps. The electron bunch width in the SPring-8 storage ring is ~15 ps. The time resolution of V1290A is 20 ps after the integral non linearity corrections. If we assume that the internal time resolution of RPC is 20ps[3)], then the remaining contributions come from Front-End-Electronics(FEEs) and are considered to be less than 40 ps. In total, the resolution of our RPC system is expected to be 50 ps.

During the development, we have produced and tested for many aspects of the RPC such as geometry of the pad/strip read-out, width of the gap, number of gap and trigger rate. The 260 $\mu m \times 2$ stacks $\times 5$ gaps $2.5 \times 100\ cm^2$ strip read-out with anode inside geometry reached a time resolution of 50 ps and an efficiency more than 99% above 10 Hz/cm^2[1)]. The coverage area is 3.2 × 2 m^2. The wall consists of 32 RPC modules as shown in fig. 2; 2 rows with 16 modules each. The size of an RPC module is 116.2 cm (L) × 24.7 cm (W) × 2.7 cm (H). The active area of an RPC module is 20.75×100 cm^2 and the active area of each RPC module overlaps about 0.3 cm with each other in the horizontal and 0.5 cm in the vertical.

Figure 2: RPC wall

The custom FEEs of our RPC including the amplifier, discriminator and stretcher were developed by Dr. M.-L. Chu. A method for the signal read-out to reduce the total number of TDC and ADC channels by half was applied, and this method is shown in fig. 3.

The special feature of the amplifier is that it is designed to minimize the reflection of the signal. The input impedance of the amplifier is set to 40 ohm and it matches well with the impedance of our RPC, which is about 30 – 40 ohm. The output signal of our custom discriminator has the same width as the input. This width is very narrow, typically around 2 ns. And this width is too narrow to be read by V1290A TDC. Therefore, we developed an additional stretcher to be placed after the discriminator to stretch the pulse width to 10 ns so that it can be read by V1290A TDC. For the timing measurement, we use CAEN V1290A TDC modules. For the charge measurement, we use LeCroy Fast Encoding and Readout ADCs (FERAs). The ADC information is used for developing correction parameters and a strip separation method.

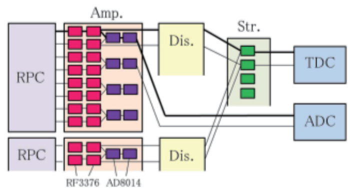

Figure 3: The sketch of FEEs for RPC

BGOegg experiment started acquiring data from April 2014, and the performance of the RPC is being checked against many aspects and the calibrations are under way to ensure the reliability of the RPC's data for physics studies in near future.

References
1) N. Tomida, H. Onishi, M. Niiyama, T. Nam, *Large strip RPCs for the LEPS2 TOF system,* Nucl. Instr. Meth. A, 766, 283-287, 2014.
2) T. Ishikawa et al., ELPH Annual Report Vol.1, 61 (2012).
3) C. Williams et al, *A 20 ps timing device-A Multigap Resistive Plate Chamber with 24 gas gaps*, Nucl. Instr. Meth. A, 594, 39–43, 2008.

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