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The development of infra-free and portable muon counting system with Hamamatsu MPPC

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We will report the development plan of an infra-free, portable and low-cost muon counting system with Hamamatsu MPPC (Multi-Pixel Photon Counter), which will achieve more frequent observations.

Muon radiography has been performed in several volcanoes and clarified the inner density structure of lava-domes. The observation at Satsuma-Iojima Island (Tanaka et.al,2009) found the density deficit which indicates the existence of high porosity region, and in Mt.Showa-Shinzan in Usu (2007), the density excess was detected which implies the intrusive magma. Its shape would be relevant to magma's viscosity. However, all of these observations were conducted where the infrastructure (e.g. electricity and road) was well-organized. If we can improve the flexibility in measurement location, more comprehensive search for various lava domes becomes possible. The comprehensive search will clarify the diversity of lava dome and its formation mechanism. For example, we can classify the vent structures of monogenetic volcanoes as Yokoyama (2010) has proposed. In addition, the simultaneous observations for three-dimensional tomography will also be more easily achieved.

The present muon detector comprised of plastic scintillators and photomultiplier tubes (PMTs) requires commercial electricity or huge solar panels (at least 1 meter square). Therefore, the measurement locations have been limited. A more power-effective and light detector has to be developed for improving the flexibility in measurement location. For these purposes, MPPC is a feasible silicon device because it is small ($<$ 1cm cube) and does not need high voltage compared with PMT (70V for MPPC and $>$ 1kV for PMT). If we can build a detector with MPPC, the power consumption of front-end electronics becomes almost negligible compared with PMT system (72W for multi-anode PMT and 8W for Cockcroft-Walton PMT). MPPC is also good at cost compared with PMT (50 USD for MPPC and 1000 USD for PMT per channel).

However, MPPC has two disadvantages to be overcome. Firstly, MPPC has a high dark-noise rate (600 kHz for 1 p.e. at T = 30 degrees Celsius). In order to discriminate muon pulses from dark-noise pulses by using coincidence technique, more than 15 (on average) muon induced photons have to be captured at MPPC's photo-cathode. This will be achieved by increasing the composition of POPOP in the plastic scintillator and optimizing the coupling of MPPC and a scintillator. Improving of the light emission efficiency in a plastic scintillator is important also in the case of PMT detector because this will lead to weight reduction of scintillators used in a detector. Second problem is that the gain depends on ambient temperature. This is also solved by changing applied bias voltage according to the air temperature variation.

In this report, the inspection of MPPC's performance including dark-noise and temperature dependence of gain will be explained. The whole design of MPPC muon counting system will be shown, focusing on the coincidence technique of discriminating muon pulses from dark-noise pulses. We will address some remarks on our developing electronics for weight and power reduction.