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MRPC technology used in muon tomography

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ABSTRACT: Since 2008, Tsinghua University has been developing Multi-gap Resistive Plate Chamber (MRPC) for the muon tomography. In 2012, we setup TUMUTY (Tsinghua University cosmic ray Muon tomography facility) based on MRPC and got some reconstruction imaging results. The RPC-type detector developed for position resolution started in 2003. T. Francke built the first position resolution RPC with a strip width between 30-50 μm, and got a position resolution about 50 μm. Then M. Petris also carried out the position resolution MRPC study using a detector of two-chamber structure with 14 gaps and 2.54 mm strip pitch. Their position resolution reached to 500 μm. Li Qite, A. Blanco, Ye Jin also studied the position resolution RPC-type detector in a detailed way. Their results proved that the RPC-type detector is a perfect choice for muon tomography.
The first generation muon tomography MRPC, the track detector in the TUMUTY, was built by Fan Xingming in Tsinghua University. The TUMUTY MRPC has a sensitive area of 736 mm *736 mm. Two MRPCs were used respectively for the X-Y dimension. Each MRPC has six gaps whose width is 0.25 mm. The readout strip's width is 2 mm and the pitch is 3 mm. Two readout boards are needed to cover an electrode because of the large sensitive area. The reason why it is called the first generation of muon tomography MRPC is that many technology has been taken into consideration, such as the efficiency at the two readout PCBs' connection area, the uniformity of the sensitive area of the detector and so on.*
*Our research is focused on developing a muon NDT (Non Destructive Testing) system that will be used in homeland security operations such as custom inspections, airport security and so on. Based on a car detection project, we developed the second generation position resolution MRPC with the same 6 gaps structure whose gap width is 0.25 mm. But the second generation detectors have a smarter structure and larger sensitive area of 1060 mm*1060 mm. Moreover, we can get X-Y two dimension readout within one detector. We move the encoding readout device into the gas box to improve the data transmission stability. Considering industrial production, studies on temperature effect and pure Freon working mode were also carried out for the second generation position resolution MRPC detectors.
Most RPC-type detectors are operating with gas mixtures containing R134a (C2F4H2) and SF6, both possess a high GWP value. The alternative eco-gas is expensive and will greatly increase the detector system's running cost. Fortunately the flux of muons from cosmic ray at sea level is low, so a kind of position resolution SMRPC (sealed MRPC) prototype working in extremely low gas flow has been developed in our team, which is called as the third generation of muon tomography MRPC. The prototype has a sensitive area of 500 mm*500 mm. It can work very well at an extremely low gas flow of 0.5 ml/min. Moreover, the performance of the detector in a mode without gas exchange is also studied. The result shows that the detector can work for more than 60 hours without any gas exchange. The calculated average gas flow of the detector reduces to 0.05 ml/min in no-gas-exchange mode. Carbon film glass and sealing bar are used in SMRPC to provide a working space instead of an aluminum gas box that the last two generations of position MRPCs needed. SMRPC makes RPC-type detector more lightweight and convenient for the industrial application.
In addition, a complete simulation framework for position resolution MRPC is built by ANSYS Maxwell+Geant4. The factors which affect the position resolution in the MRPC can be studied in detail. Machine learning method is also used for our position resolution MRPC's data processing to obtain the best performance of the detector, by training the algorithm parameters through the comparison of experimental data and the simulation data.

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