PROCEEDINGS OF SCIENCE

Micro Amplification Channels: a novel Micro Pattern Gaseous Detector for cosmic ray muon tomography

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Cosmic ray tomography consists in using particle detectors to reconstruct the scattering angle of cosmic rays traversing the volume under inspection, thus revealing the presence of materials with high atomic number. Although the validity of the muon tomography has already been demonstrated, its use on a large scale is still disfavored because of the high cost and complexity of the detectors.
We propose a novel detector (Micro Amplification Channels, MAC) specifically designed for this application, having the potential to be easily produced on industrial scale. The proposed detector belongs to the category of MPGDs with an amplification region less than 1 mm wide. The use of this device has several advantages: it allows for compact scanning stations and reduced operating costs when compared to other detectors as drift chambers and scintillators; it can be adapted to curved shape to better fit a scanning station and it is competitive from the point of view of the production costs.
The potential for industrial mass production makes the MAC a good candidate for the homeland defense market. We illustrate the basic concept of an MAC, its working principle and expected performances. The study of the capability of identifying objects made of different materials is also presented.

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1. Introduction

Cosmic ray tomography is a technique under development since years. It consists in using of particle detectors to reconstruct the scattering angle of cosmic rays traversing the volume under inspection, thus revealing the presence of materials with high atomic number, as radioactive elements or heavy metals. Although the validity of the muon tomography has already been demonstrated [1], its use on a large scale is still disfavored because of the high cost and complexity of the detectors.

We propose a novel detector (Micro Amplification Channel device, MAC) specifically designed for this application, having the potential to be easily produced on industrial scale and with a single-layer spatial resolution of the order of 500 μm.

2. The Micro Amplification Channel Device

The proposed detector belongs to the category of Micro Pattern Gaseous Detectors (MPGD). The basic structure of a MAC is a double layer printed circuit board (PCB) with two planes of strip-shaped electrodes. The PCB is then machined (mechanical milling) to obtained $\sim$300 μm deep and $\sim$500 μm wide channels representing the amplification regions. Finally, the structure is treated in a chemical bath for smoothening the strip edges. Figure 1 shows a schematic view of the MAC structure in cross-section, illustrating the production technique. The lower strips represent

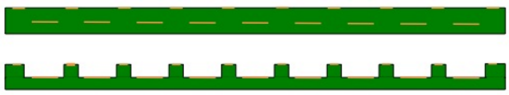

Figure 1: Sketch of a Micro Amplifier Channel device. Top: A double-layer printed-circuit board with anode and cathode strips before the milling process. Down: The MAC structure after the milling process, revealing the amplification channels.

the read-out (anode) electrodes, while the upper strips represent the cathode electrodes. Anode and cathode strips can be perpendicular to each other to form a bi-dimensional read-out system.

Advantages of the MAC device are: 1) Construction simplicity thus limited costs; 2) Potential for industrial mass production; 3) Reduced operating costs; 4) Possibility to realize compact scanning stations; 5) Adaptable to curved shapes for large angular coverage.

The MAC can be interpreted as a 3D version of a Micro Strip Gas Chamber (MSGC) [2]. Its structure recalls the MGD [3], the main difference is the simpler production technique of the MAC, reflecting to a different geometry of the detector, in particular the shape of the amplification channels.

3. Micro Amplification Channel Working Principle

The amplifying structure of a MAC device is completed with a drift electrode placed a few mm above the top of the PCB, defining the ionization (drift) region. The enclosed volume is filled with a simple gas mixture (Ar:CO_2 93%:7%). High voltages are applied to the drift electrodes and to the cathode strips to create electric fields in the ionization and amplification regions, respectively. Primary electrons created in the gas volume drift following the field lines and get multiplied entering the amplification channels. Figure 2 shows the electron drift lines in a MAC device and the ionization-drift-multiplication process occurring in the detector traversed by a muon. Layout

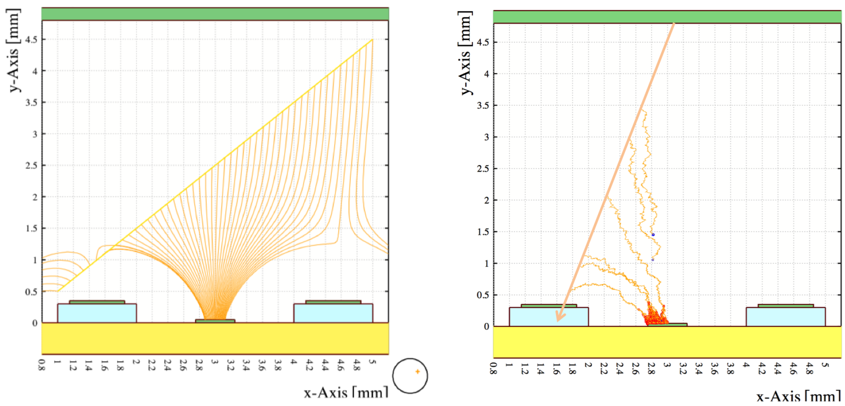

Figure 2: Left: electron drift lines of a MAC. Right: muon traversing the active volume of the detector. Primary electrons are generated along the muon track; following the drift lines they are driven into the amplification region where the multiplication process takes place.

optimization (strip pitch and width, channel dimensions, drift gap size) of the MAC structure is ongoing. The expected single-layer spatial resolution is of the order of 500 μm.

Figure 3 shows the amplification as a function of the voltage applied to the cathode strips. The expected gain for an amplification voltage of 2100 V is of the order of 5×10^3. The problem

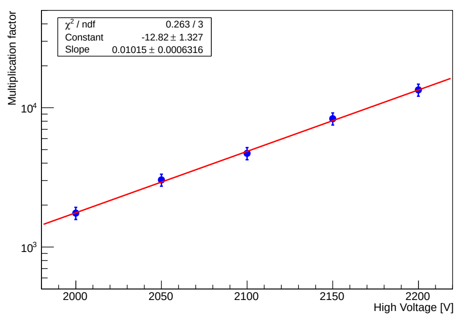

Figure 3: Expected gain of a MAC as a function of the amplification voltage.

of sparks, common to all MPGD, is reduced, with respect to MSGC, by optimizing the channel dimension. The addition of a resistive protection layer on the anode strips can be considered, following the developments done for Micromegas [4].

4. MAC for Muon Tomography

Simulations show that with tracking performance easily achievable with a scanning station based on MAC detector, small blocks of heavy materials can be identified with an exposition time of few tens of minutes, figure 4. Improvements of the scanning power can be obtained by optimizing the reconstruction algorithm and the detector geometry. Finally, MAC device has self-triggering

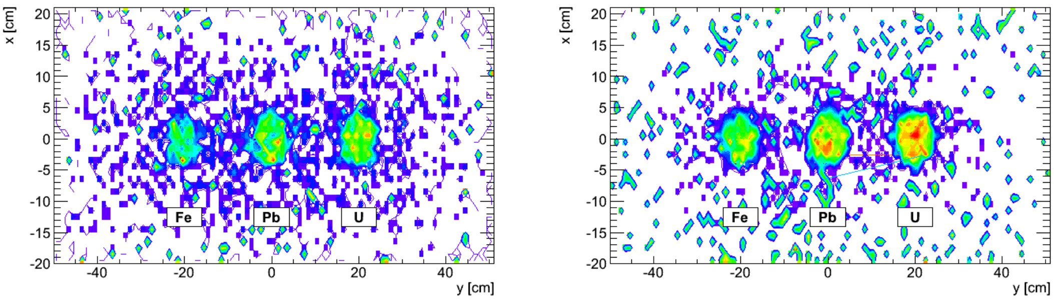

Figure 4: Reconstruction of 4 cm-diameter spheres of Fe, Pb and U with the expected performance of a scanning station based on MAC (500 μm spatial resolution, 3 mrad angular resolution). Scattering angles are reconstructed with a Point Of Closest Approach algorithm. Exposition time = 10 min (left), 45 min (right).

capability, thus allowing the realization of a scanning station completely based on this detector with no need of additional trigger devices.

5. Summary and Outlook

We propose a new MPGD device, (Micro Amplification Channel, MAC) specifically conceived for applications requiring large-area coverage, moderate tracking power and limited rate capability, such as muon tomography. The simplicity of the construction procedure and the potential for industrial mass production make the MAC a good candidate for the homeland security market. Other possible applications of the MAC detectors are: high energy physics experiments with low particle fluxes (cosmic ray experiments on Earth, underground experiments) as well as geological applications (soils densitometry). The first MAC small-size prototypes are currently under construction. Future extension to larger area and the realization of a prototype scanning station based on MAC is foreseen.

6. Aknowledgements

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