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Multigap Resistive Plate Chambers for EAS study in the EEE Project

M. ABBRESCIA[9], S. AN[11], R. ANTOLINI[6], A. BADALA'[4], R. BALDINI FERROLI[2,3], G. BENCIVENNI[3], F. BLANCO[4], E. BRESSAN[2,1], A. CHIAVASSA[5], C. CHIRI[2,8], L. CIFARELLI[1], F. CINDOLO[1], E. COCCIA[6], S. DE PASQUALE[7], A. DI GIOVANNI[6], M. D'INCECCO[6], F. L. FABBRI[3], V. FROLOV[5], M. GARBINI[2,1], C. GUSTAVINO[6], D. HATZIFOTIADOU[1], G. IMPONENTE[2], J. KIM[11], P. LA ROCCA[4], F. LIBRIZZI[4], A. MAGGIORA[5], H. MENGHETTI[1], S. MIOZZI[3], R. MORO[2,6], M. PANAREO[8], G.S. PAPPALARDO[4], G. PIRAGINO[5], F. RIGGI[4], F. ROMANO[9], G. SARTORELLI[1], C. SBARRA[2,1], M. SELVI[1], S. SERCI[10], C. WILLIAMS[1], A. ZICHICHI[1,2,12], R. ZUYENSKI[8]
[1]*INFN and Department of Physics, University of Bologna*
[2]*Museo Storico della Fisica, Centro Studi e Ricerche "E. Fermi", Roma*
[3]*INFN, Laboratori Nazionali di Frascati*
[4]*INFN and Department of Physics and Astronomy, University of Catania*
[5]*INFN and Department of Physics, University of Torino*
[6]*INFN, Laboratori Nazionali del Gran Sasso*
[7]*INFN and Department of Physics, University of Salerno*
[8]*INFN and Department of Physics, University of Lecce*
[9]*INFN and Department of Physics, University of Bari*
[10]*INFN and Department of Physics, University of Cagliari*
[11]*World Laboratory, Lausanne, Switzerland*
[12]*CERN Geneva, Switzerland*
giovanni.imponente@cern.ch

Abstract: To detect muons in extensive air showers, as well as looking for unexpected cosmic events, the Extreme Energy Events (EEE) Project has installed telescopes of Multi-gap Resistive Plate Chambers (MRPC) in many Italian High Schools. The EEE MRPCs are a large and cheap version of the detector designed for the Time Of Flight measurements in the ALICE experiment at the LHC collider at CERN. Exploiting the concept of the multiple small gas gaps (small λ) combined with the use of high gain (large α) and fast gas mixture (Freon and SF_6 based), the MRPCs show a time resolution of the order of 100 ps.
Particle tracking is performed equipping the MRPC with 24 copper strips (3.2 cm pitch), glued on a vetronite panel and then on a honeycomb one, acting also as main support of the glass planes. The longitudinal coordinate is obtained from the arrival time difference between the two signals collected at the two edges of the fired strip by the front-end electronics based on the fast NINO Asic. The time measurement is made with commercial multi-hit TDCs. A space point resolution of $\sim 1\ cm^2$ is obtained using commercial multi-hit TDCs. The MRPCs for EEE experiment are built at CERN by Italian High School students and teachers under the supervision of INFN and Centro E. Fermi experts. At present a total of 72 MRPC has been built and tested. Some telescopes have been installed in High Schools and INFN sites of 7 pilot cities, distributed along Italy, namely Bologna, Cagliari, Catania, Frascati, L'Aquila, Lecce and Torino. Here first results and performances of these MRPC are presented.

Introduction

The detection of Extensive Air Shower (EAS) through an array of muons detectors installed in many Italian High Schools is one of the main purposes of the *Extreme Energy Events* (EEE) Project conceived by Antonino Zichichi which is starting its data-taking stage [1, 2]. The good timing reso-

lution allowed by Multigap Resistive Plate Chambers (MRPCs) [3], together with the modularity are one of the most promising features in order to reconstruct EAS at ground.
Each detector, a muon telescope (Figure 1), is made of three MRPCs, to track the direction of muons with an absolute time stamp given by a GPS module.
We present some of the preliminary tests performed in the first stations running and initial data-taking and analysis. For more details on the up-to-date report on the EEE Project see also [4, 2].

Experimental outlook

Each of the 3 MRPC ($80 \times 160\ cm^2$ active area), assembled in a telescope as in Figure 1, is made of six gas gaps of 300 μm in a stack of glass sheets [4, 2], filled with a mixture of 98$\%$ of $C_2F_4H_2$ and 2 $\%$ of SF_6 working in avalanche mode. It has been possible to run the MRPC without gas flow for more than a month, without any remarkable loss of efficiency and with a modest current flow increase [5].
Through DC-DC converters, a low voltage (0-5 V) supplies a high voltage (± 10 kV), applied on top and bottom glass sheets of a MRPC. The signal induced on the 24 copper strips along the chambers (see figure 2) is sent to front end electronics based on ultra-fast and low power amplifier/discriminator (NINO-ASIC) [6].
A total of 144 channels provides signal time measurements on each telescope using commercial multi-hit TDCs. The Data Acquisition system is VME based; a LabView DAQ Program runs on a Windows PC, connected to the VME crate via a CAEN USB-VME bridge.

Time difference analysis

The (x,y) coordinates of the through going particle (mostly muons) impact point on a chamber are obtained from the hit strip in one direction and from the time difference of the signals arriving to the left and right strip edges in the other direction. The time difference distributions have been analyzed in order to properly reconstruct the particles traversing the telescope. We studied in details the distributions of the differences of arrival time of signals, chamber by chamber and strip per strip and from some slightly de-centered distributions we have quantitatively corrected those measurements, gaining at the end a better spatial resolution. In the following a self calibration procedure is described to achieve the time-space relationship by means of the MRPC signals, without using any external trigger. In Figure 3 we show a typical distribution of the difference between the time measurement on the left side and the corresponding measurement on the right side on a single strip and the corresponding fit.

Figure 1: Typical set up of the MRPC telescope.

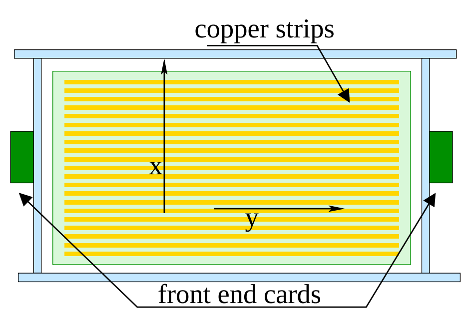

Figure 2: Schematic view of the inner part of a MRPC (top view): the signals are formed in the gas gaps between thin glass layers and travel on the longitudinal copper strips towards both ends.

The time measurements are converted to *position* taking into account the strip length L, setting the origin of the horizontal axis, y coordinate, at $L/2$, i.e. in the middle of a strip. The time measurements on the left and on the right side are related to the impact point y by:

$$v_s t_l = \frac{L}{2} + y\,, \qquad v_s t_r = \frac{L}{2} - y \qquad (1)$$

where v_s is the signal propagation velocity, so that

$$y = \frac{v_s}{2}(t_l - t_r)\,. \qquad (2)$$

Looking to the time difference distributions, strip by strip, we can estimate:

1. how much they are not symmetric with respect to zero;
2. the velocity of the signal along the strips *directly from the data*.

In particular, to do this the left-right time distributions have been fitted by means of a convolution of a flat one, taking into account two effective edges, a and b, with a Gaussian one, taking into account the experimental resolution:

$$T(t) = \frac{1}{N}\int_a^b \exp\left(-\frac{(t-t_0)^2}{2\sigma^2}\right) dt_0\,. \qquad (3)$$

Using the MINUIT package we get, for each strip, the parameters N, a, b, σ. The average final speed value is $(v_s)^{-1} = 6.1 \pm 0.1\ ns/m$. The quoted error takes into account the difference among the various strips, whose distribution is a Gaussian one as expected. The parameter σ is consistent with the chamber longitudinal resolution, as reported in the following, and about $1\ cm$ inefficiency at the edge.

Spatial resolution

The telescopes running with low gas flow and at high voltage above the knee of the efficiency curve ($\sim 18\ kV$) (see [2]) have been operating in the schools for several months, since May 2006. To evaluate the spatial resolution we selected events having only one hit per chamber, i.e. the cleanest ones (about 10% of the total).

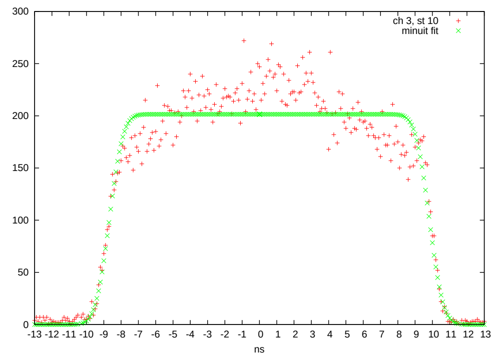

Figure 3: Typical distribution of left-right time difference for a single strip and corresponding fit with the function in Eq. (3), in units of ns.

The spatial resolution has been measured studying the distribution of Δy_2 defined as

$$\Delta y_2 = \frac{y_1 + y_3}{2} - y_2\,, \qquad (4)$$

being y the coordinate of the impact point along the strip, indexes 1,2,3 referring to bottom, middle and top chambers, respectively, so that Δy_2 is the distance between the expected hit on the middle chamber and the measured one. Thus the resolution on the impact point y coordinate is

$$\sigma_y(cm) = \sqrt{\frac{2}{3}}\,\sigma_{\Delta y_2}(cm)\,. \qquad (5)$$

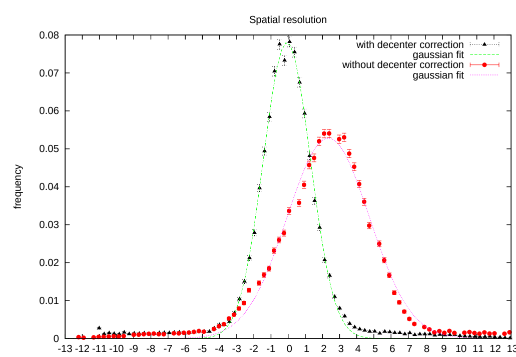

Figure 4: Δy_2 expressed in cm, before (red) and after (green) the strip alignement.

Applying the corrections obtained from fitting the time distributions on the single strips has allowed to obtain a histogram centered and with a width of $1.4\ cm$, whereas it is of $2.4\ cm$ without the self-calibration centering procedure (Figure 4). Corrections due to the pulse height have still to be applied, looking to the measured signal time over threshold.

We also evaluated the spatial resolution in the direction transverse to the strips (x coordinate), gaining directly a centered distribution and a spatial resolution of 0.25 in units of strips which, taking into account the strip pitch (3.2 cm), corresponding to $0.8\ cm$, as shown in Figure 5.

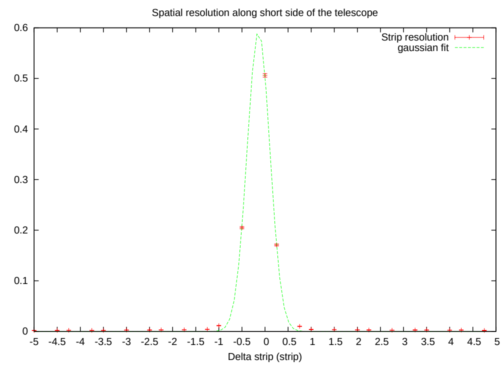

Figure 5: Spatial resolution (in units of strips) in the direction transverse to the strips.

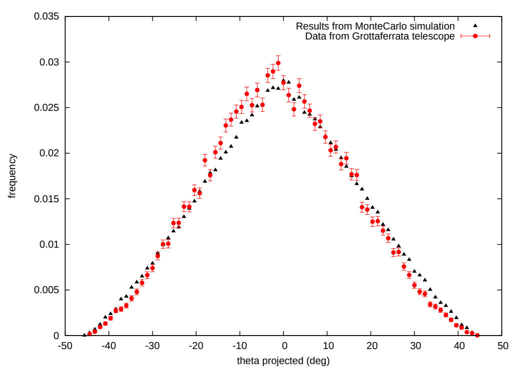

Figure 6: Comparison between muon zenith angle projection from data and Monte Carlo.

Muon reconstruction vs MC simulation

We performed a MonteCarlo simulation to evaluate the acceptance of our telescope taking into account the dimensions of the MRPCs effective area, i.e. length 158.0 cm, width 80.0 cm, vertical distance between single detectors 80.0 cm and a total of 16.6 % has been obtained, taking into account the muon vertical distribution. Furthermore we evaluated the reconstructed muon zenith angle by looking at the distribution of its projection on one orthogonal plane, in particular on the $y - z$ one, z being the vertical direction. Preliminary results involving such angular distribution are plotted in Figure 6, togheter with the corresponding results obtained with Monte Carlo simulation. The figure shows a good agreement between data and simulation.

Conclusions

MRPCs as particle detectors for the EEE Project devoted to the detection of muons are running properly and the first data show the expected performances are achieved. The left-right time distributions have provided a technique to measure the effective speed of the signal along the copper strips and a reliable correction procedure to improve the spatial resolution, up to $0.8 \times 1.4\ cm^2$. The installation of telescopes inside schools started and by the end of 2007 all the pilot towns will have a running telescope opening the way to search for time correlations between far away sites.

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