A low-resistivity RPC for the trigger of the ALICE dimuon arm

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Abstract: Resistive Plate Chambers (RPC) operated in streamer mode are expected to provide the trigger of the ALICE dimuon forward spectrometer. To match the requirements concerning the rate capability (about 100 Hz/cm^2, including a large safety factor), several prototypes have been realized with low-resistivity Bakelite electrodes and a strongly quenching gas mixture. During beam and irradiation tests the detector has shown a stable behavior and excellent rate capability (up to 1 kHz/cm^2 in beam tests) with a cluster size close to one. In addition to that, a new discrimination technique with a dual threshold has been devised: with this method, a time resolution comparable with the one typical of the avalanche mode can be obtained as soon as the applied voltage is sufficient for the RPC to reach full efficiency. In the presentation the performances of the detector will be reported, together with the results of ageing tests performed at the Gamma Irradiation Facility at CERN.

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1. Introduction

The ALICE experiment [1] will study ultrarelativistic heavy-ion collisions at a center-of-mass energy $\sqrt{s}$= 5.5 TeV/nucleon, obtainable at the forthcoming LHC at CERN. The principal aim is to study the behavior of nuclear matter at high temperature and energy density, with particular attention to the predicted phase transition to the deconfined state called Quark-Gluon Plasma. One important signature of deconfinement is the production

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pattern of heavy quarkonium (J/ψ, Υ and their excited states): a Forward Muon Spectrometer [2] has been specifically designed to study heavy quarkonia production through the muonic decay channel.

To match the DAQ bandwidth dedicated to the spectrometer (acquisition rate = 1kHz) it is necessary to select the events by means of a cut on the transverse momentum of muons: the informations needed will be collected by the two Trigger Stations, made of two detector planes each, covering an area of about 6×6 m^2, placed respectively 16 m and 17 m from the interaction point in the rapidity region 2.5<y<4 (i.e. between 2° and 9° with respect to the beam line). The dectector must have a time resolution of few nanoseconds, in order to sample the signals in a 20 ns time window; the strip width will be smaller in the area closer to the beam line, going from 1 to 4 cm. The cluster size has to be as close as possible to one, in order to reduce occupancy and increase selectivity: moreover, a rate capability of 100 Hz/cm^2 is needed (including a large safety factor). These requirements are fulfilled by the low-resistivity Resistive Plate Chambers operated in streamer mode, which are the current choice for the dimuon trigger detector.

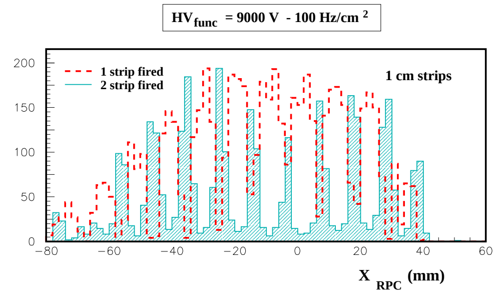

Figure 1: Distribution of impact points in events with 1 or 2 strips fired.

2. Low-resistivity RPC

RPCs [3] [4] can be operated in two modes, determined by the multiplication process: when it degenerates in sparks we have the streamer mode, when sparks do not take place, the RPC operates in the avalanche mode.

The streamer mode is characterized by the large signals induced by sparks, that do not need amplification and that have a Gaussian spectrum, easing the task of discrimination. The cluster size is then small, as well as the single rate: the Time Of Flight (TOF) distribution shows a good average resolution, but at low operating voltages it is affected from a 'tail' of late signals due to sparks delayed with respect to the primary avalanche. The main drawback of the standard streamer mode is however the limited rate capability, too low for operation in the ALICE environment, due to the great amount of charge delivered to the resistive electrodes.

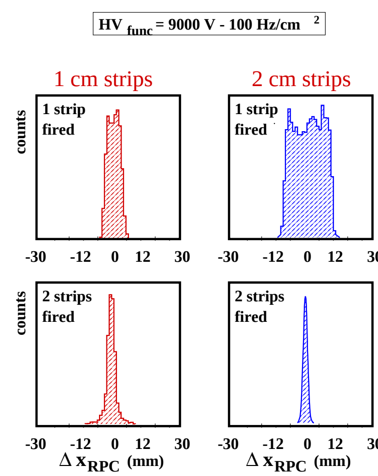

Figure 2: Distribution of deviations between assigned and true impact points.

To take advantage of the good characteristics of cluster size and simplicity obtainable with the streamer mode, we tried to increase the rate capability realizing prototypes of single-gap RPCs (gap thickness: 2 mm) using 2 mm thick electrodes, made of low-resistivity Bakelite ($3{\cdot}10^9$ $\Omega{\cdot}$cm), and a low-gain gas mixture composed of 49% Argon, 40% Tetrafluoroethane, 7% Isobutane and 4% SF_6. The prototypes have been tested at the SPS at CERN in 1998 [5], and have shown a stable behavior, rate capability of a few hundreds Hz/cm^2, a sufficiently good time resolution (98% of events are in a 20 ns time window), negligible single rate (0.1 Hz/cm^2), and a small cluster size (1.2 for 2 cm wide strips).

3. Position resolution

In beam tests carried out in 1999-2000 with 7 GeV/c pions at the T10 experimental area at CERN's PS, the position resolution of the low-resistivity RPC equipped with 1 cm and 2 cm wide strips has been studied in detail, with the help of the T10 tracking system based on MWPC. In fig. 1 it is shown the the impact point for 1 and 2 strips fired on a RPC equipped with 1 cm wide strips: the shape of this distribution led us to associate events with cluster size = 1 to the center of the fired strip, and to assign events with cluster size = 2 to the point between the two fired strips.

In fig. 2 there the deviations between the assigned impact points and the real impact points are plotted, calculated by means of the tracking system. The position resolution (r.m.s.) measured with the help of these distributions for 1 cm wide strips is 2.4 mm with cluster size = 1 and 1.5 mm with cluster size = 2; in the same way, for 2 cm wide strips the r.m.s. values are respectively 5.9 mm and 0.9 mm. These results are very close to the theorical value $w/\sqrt{12}$, where w is the strip width.

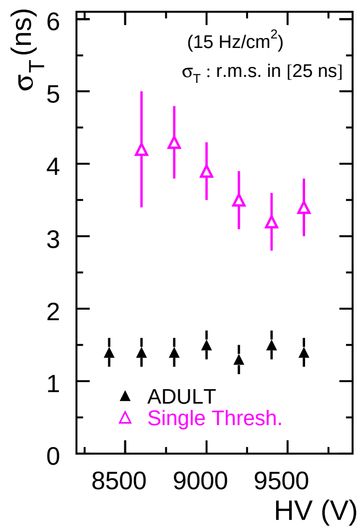

Figure 3: Comparison of time resolution between standard discriminators and ADULT

4. The ADULT discrimination technique

The analysis of streamer signals with oscilloscopes shows that sometimes the spark is delayed in respect to the avalanche induced by the primary electrons: this happens if, due to statistical fluctuations, the gain of the primary avalanche is too low to fulfill immediately the Raether condition for streamer formation. This phenomenon determines double peaks on TOF spectra obtained with conventional discriminators, thus worsening the time resolution. The problem can be corrected increasing the operating voltage of the detector, but this causes a deterioration of the cluster size.

An elegant way to solve this problem has been found by means of a new discrimination technique. ADULT [6] (A DUaL Threshold discriminator) is based on a double threshold system: a low threshold (10 mV) which provides the time reference, and a high threshold (50-80 mV) for streamer validation. The two signals are put in coincidence: the low-threshold one is delayed in order to give the start of the coincidence. In this way, the signal issued at the output is always synchronized with the initial avalanche. The maximum delay allowed for the high threshold signal with respect to the primary avalanche has been tuned to 10 ns. This system is very effective in suppressing the tail of late signals: the time resolution (fig. 3) is comparable with the avalanche mode already at the plateau knee (8900 V). Moreover, it makes possible to strobe the signals in a shorter time window, in order to reduce the background hits.

5. Ageing test: effects of dry gas flow on bakelite resistivity

Since the resistivity of the electrodes is of paramount importance for the rate capability of the RPCs, it is important to be sure that this parameter remains stable also after continuous operations. Since it has been reported that prolonged exposition of Bakelite sheets to dry gas can indeed increase the resistivity of the material, we have realized a special test to measure the magnitude of the effect relative to our standard gas mixture, compared with the same mixture to which 1% of water vapor was added. To this end we have realized two dummy RPCs, made out with 50×50 cm^2 Bakelite sheets coated with linseed oil not diluted and separated by a gas gap 3 mm thick. The two dummy chambers have been fluxed for 4 months with a gas flow of 30 cc/min, and opened from time to time to measure the resistivity of the Bakelite electrodes. The results of the measures, corrected for the different temperatures, are shown in fig. 4: the resistivity of the bakelite flowed with the dry gas mixture has increased by a factor of 2, while the resistivity of the humid-flowed sheet remained basically unchanged.

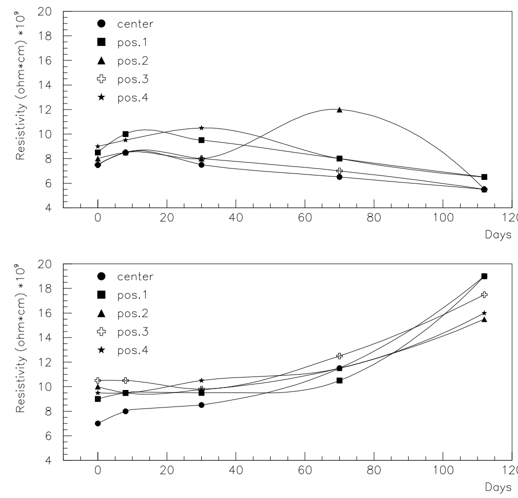

Figure 4: Resistivity of dummy RPCs flowed with dry (bottom) and humid (top) gas mixtures

6. Ageing tests at the GIF

To evaluate long-term effects on the detector characteristics due to prolonged exposition to the ALICE background, we have performed several ageing tests at the Gamma Irradiation Facility at CERN in February, 2001. During the one-month long run the detectors have been exposed to a gamma ray flux such as to induce counting rates comprised between 50 and 150 Hz/cm^2. During the irradiation, the efficiency of the chambers for cosmic rays was measured, together with parameters such as dark current and single rate. At the end of the run the detector accumulated an integrated current of about 30 mC/cm^2, equivalent to 10 month of operation with Pb-Pb collisions at ALICE. We shall present results concerning two detectors which were realized with melamminic Bakelite, of resistivity $1.5{\cdot}10^9$ $\Omega{\cdot}$cm:

in one case the electrodes were coated with diluted linseed oil, while in the other detector the oil treatment was absent.

The behavior of the oiled detector has been quite satisfactory, but two problems were detected: a shift of the efficiency plateau towards higher H.V. (fig. 5) and an increase of dark current and single rate. On the other side, with the detector without linseed oil we met difficulties in reaching the efficiency plateau, and the dark current was very high (hundreds of μA even without irradiation). To investigate further this question, in June, 2001 another ageing test one-month long has been carried out at GIF: in this case, a detector with a double layer of diluted linseed oil has been tested. Moreover, the detectors have been flowed for a two-week period with a gas mixture similar to our standard one, but with a percentage of SF_6 reduced to 1%. The preliminary results concerning these tests are quite encouraging: after an integrated current of about 60 mC/cm^2, i.e. twice the value accumulated in the February test, the double oil layer doesn't seem to bring any noticeable negative effect, and the increase of current and of the single rate was sizeably slower in the double-oiled RPC than in single-oiled chambers; the same beneficial effect has been noticed for the new gas mixture.

7. Conclusions

The low-resistivity RPC has shown good overall characteristics in beam tests, with a small cluster size and a good position resolution. The ADULT discrimination technique is useful to eliminate the problems arising from delayed streamer which affect the TOF distribution, and it makes possible to operate the chamber at voltages close to the efficiency knee, thus preserving low values of cluster size. After prolonged operation under uniform irradiation, the detectors have shown a rise of dark current and of single rate, but preliminary results seem to indicate that multiple layers of oil can cure the problem and extend the lifetime of the detectors up to over 20 months of Pb-Pb collisions in ALICE.

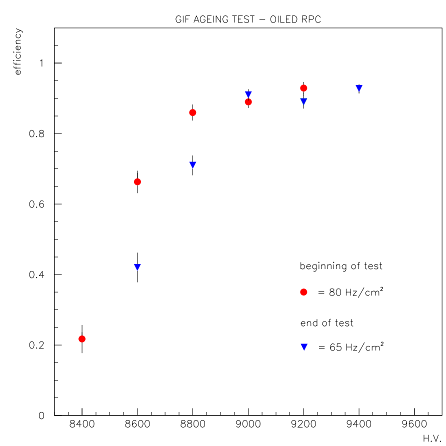

Figure 5: Comparison of efficiency plateau at the beginning and at the end of aging run

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