

High counting rate transition radiation detector

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Abstract

A new Transition Radiation Detector (TRD) prototype with high granularity for a high counting rate environment, required by the CBM experiment at the future experimental facility FAIR, GSI-Darmstadt, was designed and built. A solution for such a detector is a multiwire proportional chamber with a minimized drift region, reduced to a cathode – readout pad plane distance of 6 mm and a multiwire anode plane in the middle. Results of the ^{55}Fe source tests and of the in-beam investigations of the rate capability in terms of signal deterioration and position resolution degradation with the increase of the counting rate are presented. Based on the measured deposited energy spectra, the discrimination between electrons and pions as a function of number of layers was estimated by Monte Carlo simulations.

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1. Introduction

The next generation of experiments in hadron physics, as is the CBM experiment [1] at the future experimental facility FAIR, GSI-Darmstadt, has to be able to measure extremely rare signals.

This requires high interaction rates that impose to the detectors unprecedented performances in terms of speed, granularity and radiation hardness.

The main challenge for the R&D activity of gaseous detectors for such experiments is to develop fast detectors which keep their performance in a high counting rate environment.

The expected particle rates for the CBM-TRD subdetector, in particular at small polar angles, are up to 10^5 particles/cm² s for 10^7 interactions/s of minimum bias Au + Au collisions at 25 A GeV [1].

Two concepts of TRD are well known by now: the ALICE-TRD [2] using a high granularity readout electrode gives very good performance in a high multiplicity environment and at low counting rate, and the ATLAS-TRT [3] based on straw tubes, with lower granularity but a

good performance up to a counting rate of 10^6 particles/cm² s.

Based on these considerations, a natural solution for a fast TRD detector with a high granularity which could fulfill the requirements of the CBM experiment would be a Multiwire Proportional Chamber (MWPC) with a minimized drift region of 3 mm, in order to reach the required speed of the readout of the signals and to reduce the possible space charge effects. A pad readout electrode with a corresponding granularity has to be used in order to reach the desired occupancy per event [1].

This paper presents the results of the tests performed with such a prototype. Section 2 describes the basic principle of the design and the construction of the prototype. The results of the measurements with an ^{55}Fe source and in-beam, performed at the SIS accelerator of GSI-Darmstadt, are described in Section 3. Section 4 is dedicated to the conclusions.

2. Detector description

The new TRD prototype is composed of a radiator and a MWPC, a sketch of the counter structure is shown in Fig. 1.

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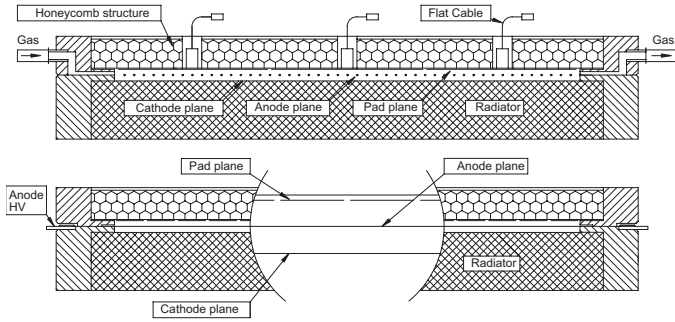


Fig. 1. Cross-sections through the detector: perpendicular (upper part) and parallel (lower part) to the direction of the anode wires.

The chamber has a symmetric structure with the anode wire plane situated in the middle, at 3 mm distance, between the cathode plane and, respectively, the readout pad plane electrode. In order to reduce the possible space charge effects by reducing the amount of charge amplified at each anode wire (W–Au, 20 μ m), a small pitch of 2.5 mm between anode wires was used. The pads are grouped in three rows along the anode wires with 30 pads per row. Each pad has a rectangular shape and an area of about $7.5 \times 80 \text{ mm}^2$ (the pad width is along the anode wire direction). The readout pad plane is reinforced by a honeycomb structure. The radiator (Rohacell foam HF71) is in contact with the cathode plane made of an aluminized mylar foil (25 μ m). The counter has an active area of $240 \times 240 \text{ mm}^2$.

3. ^{55}Fe source and in-beam tests

3.1. Source measurements

The prototype was tested at different anode voltages using an ^{55}Fe source and an Ar/CO₂(85%/15%) gas mixture.

The pad signals were amplified by a custom built charge sensitive preamplifier/shaper (PASA) based on discrete components. It has a gain of 2 mV/fC and a noise of 1800 electrons r.m.s. The charge or pulse height information was obtained as the sum of the sampled charge information, delivered by a FADC converter of 33 MHz sampling frequency, on the three consecutive pads in a row fired in an event (the pad with maximum charge (p_i) and its left (p_{i-1})–right (p_{i+1}) neighbours), in order to obtain the total deposited charge. The obtained energy resolution from the Gaussian fit of the main peak of the ^{55}Fe X-ray source was 8.6% (σ) (Fig. 2).

3.2. Experimental setup for in-beam measurements

The in-beam tests have been performed at the SIS accelerator of GSI, Darmstadt in a joint measurement campaign of the JRA4-I3HP Collaboration.

The prototype (Buch-TRD) has been placed between two plastic scintillators (PI1 and PI2, each with an area of

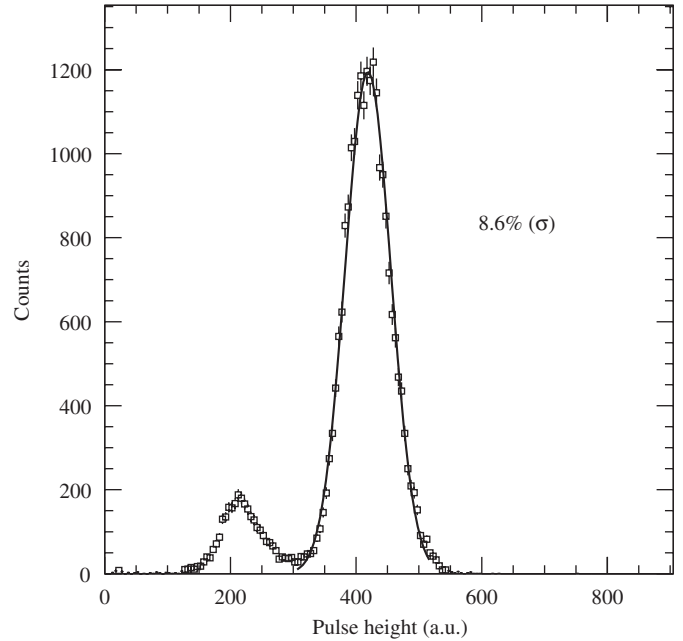


Fig. 2. The energy spectrum of the ^{55}Fe source with an Ar/CO₂(85%/15%) gas mixture, at 1700 V anode voltage.

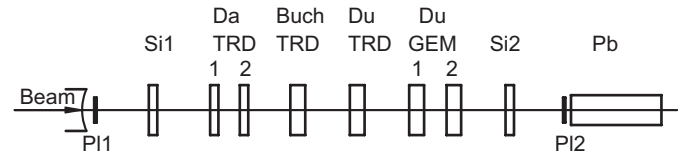


Fig. 3. Experimental setup used for the beam tests. The prototype discussed here is marked as Buch-TRD.

$5 \times 5 \text{ cm}^2$), used for time of flight (TOF) information and as a beam trigger, and between two double sided silicon strip detectors (Si1 and Si2, each with an active area of $32 \times 32 \text{ mm}^2$, 50 μ m strip pitch) for the beam profile definition. Electrons and pions are tagged using the information provided by a lead glass calorimeter (Pb) placed along the beam line (Fig. 3).

The amplification of the signals was made by the same PASA used for the source tests. The digital conversion of the signals was made by a FADC converter with 33 MHz sampling frequency (0.6 V swing and an adjustable baseline). The MBS – DAQ system [4] was used for data acquisition.

3.3. In-beam test results

The effect of the high counting rate environment on the detector performance was studied using a mixture of positive particles of 2 GeV/ c momentum, in which the protons have been the dominant component. The counting rate per area of detector was changed by varying the extraction time of the beam at a given beam intensity. The protons were selected using TOF information. The charge

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