A versatile setup for studies of tracking and particle identification with drift chambers and GEM amplification stages

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Gaseous tracking detectors play a key role in existing and planned hadron and particle physics experiments. A universal device has been set up for optimizing the tracking performance of existing (ANKE at COSY, WASA at COSY) and for developing new concepts (PANDA@FAIR). In previous reports [1], [2], [4] a detector containing a Gas Electron Multiplier [3] was inserted in a drift chamber (GEM DC) for tracking and charged particle identification (PID) by multiple ionization measurements was (fig.1). Here we present new results on the development of this device and measurements performed with the use of Fast QDC - a flash ADC with a sampling frequency of 160 MHz (WASA at COSY experiment).

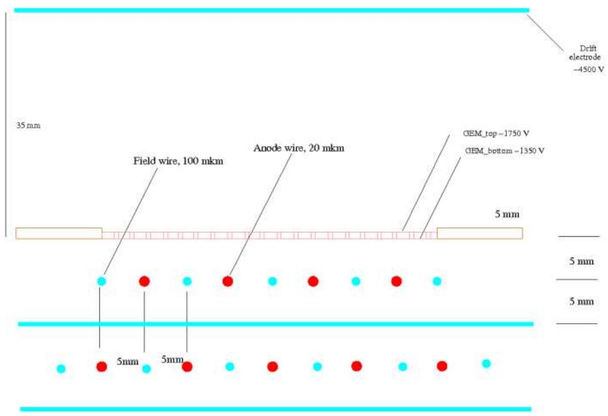

Fig. 1: The geometry of the GEM DC chamber

For the flexibility of investigations three independent high voltages are applied to GEM DC: a drift potential, a top GEM potential, and a common potential on the bottom GEM electrode and cathode. The last potential defines the gas amplification in a drift chamber on the wires, while the first and second provide the drift electric field and the amplification inside the GEM foil. The main functions of the introduced GEM stage is to improve the single electron sensitivity and to provide more performance flexibility. The overall charge amplifications of the detector can be shared between the preamplification in the GEM itself and the amplification on the anode wires. Since the majority of ionization clusters are single electrons this additional amplification in GEM can be critical to improve the efficiency of cluster registration. Keeping a relatively small GEM amplification [5] provides an efficient suppression of the positive ion backflow into the drift volume - one of the major problem in Time Projection Chambers (TPC) especially for high rate applications. The GEM foil forms a sharp transition region between low drift field in a drift volume and relatively high field in the volume of the drift chamber providing a time expansion of the distances between ionization clusters. With appropriate settings of the electrode potentials an adjustment of the drift velocity, electron diffusion, overall charge amplification and transfer can be investigated and optimized. A signal induced on the bottom GEM electrode can be also used for trigger purposes.

In addition a module of a 6 plane drift chamber and a module of a 2 layer straw tube detector (ANKE at COSY) are placed on the top and bottom around the GEM DC together with two scintillation counters for cosmic ray triggering and external tracking.

In the GEM DC signals from anode wires were registered using a fast transresistance current amplifier with a gain of 10 $mV/\mu A$ and a risetime of about 8 ns. The bipolar signals are then transfered into unipolar ones by a booster amplifier [6] and through coaxial cables are sent to the FQDC [7] where the digitization is done. The FQDC has a FPGA programmed algorithm which identifies the number of pulses in the readout window (up to 40 pulses in a window of 6.4 μs maximal width) and analyzes the time position, amplitude and charge of each pulse.

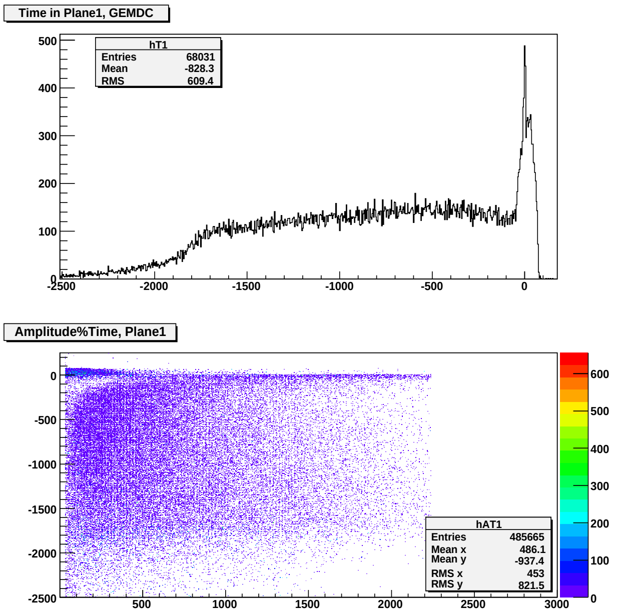

Fig. 2: Time spectrum (top), Amplitude time - correlation (bottom), high voltage on GEM 400V, drift field $E_{dr} = 42.9\,V/cm$

Cosmic ray data were obtained with the following high voltage settings: cathode and GEM_{bottom} - 1.4 kV, GEM_{top} - 1.8 kV, drift - 1.95 kV. This corresponds to a GEM voltage of 400 V, and $E_{dr} = 42.9\,V/cm$.

The relatively low drift field assures for this gas mixture $(80\% Ar + 20\% C_2H_6)$, higher cluster registration efficiency due to low drift velocity and therefore bigger time intervals between ionization clusters.

The time spectra and correlations amplitude-time, amplitude - number of pulses and time - number of pulses (fig.2, fig.3) are presented for one selected central channel. The wide region spreading practically from T=0 till the maximum negative limit corresponds to the maximum drift time which depends on the drift velocity and therefore on the drift field. This is a basic working domain for the registration of the ionization clusters produced in the drift volume.

Several identical GEM DC modules consecutively rotated by 90 degrees (X-Y-X-Y) for better pattern recognition can be exploited for particle ionization measurements and tracking together and complementary with an external tracking device

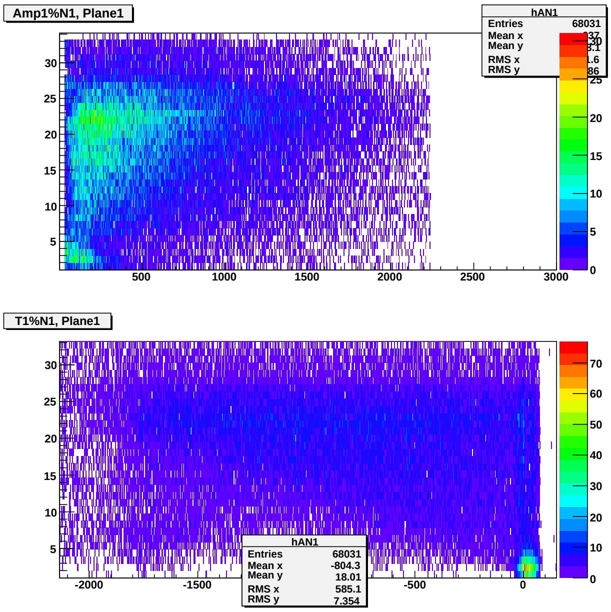

Fig. 3: Correlations amplitude- number of pulses (top), time - number of pulses (bottom), high voltage on GEM 400V, $E_{dr} = 42.9\, V/cm$ drift field

or without it. Each module represents in some sense a small one projectional TPC. One additional DC plane will provide a coordinate point in order to fix together with GEM DC itself the track crossing point in the GEM DC anode plane. Combining the information from other modules this permits the spacial track angle determination. Track fitting with hits from ionization clusters will be performed. Some preliminary calibration procedures would be necessary in accelarator beam test runs to obtain precise correction for the time - coordinate relation. During this calibration the drift times will be associated with the cluster z-coordinate (along the beam direction) for tracks with different angles. At the same time a flash ADC will provide in addition to time positions the amplitude, the charge and the number of clusters. Two methods can be applied simultaneously and independently [8], [9] to measure the particle ionization loss (dE/dx). The truncated mean method provides the dE/dx estimator by excluding the measurements (i.e. clusters) with highest energy depositions (from 40% to 60% of the highest amplitudes) and calculats the mean value of the remaining samples. Thus the contribution of the long Landau distribution tail is reduced and the PID resolution is improved.

In the second method the number of clusters per particle track is taken as an estimator of the specific ionizations. Since the number of primary ionization clusters follows the Poisson distribution which is narrower than the Landau distribution one can expect a comparable or better dE/dx resolution. Using this method in principle gives an opportinity of a simplified digital readout version for the detector with no flash ADC and only an amplifier-discriminator and a simple logic which can be also used for fast second level triggering.

A proposed version of the detector is simple and cheap in comparision with a classical TPC. A small drift volume is supposed to be used in four modules of detectors: 10 - 15 cm (typically 1 m and more in a TPC). This provides a significant reduction of the detector size and improves the rate capabilities with respect to standard TPCs in high intensity applications. The detector contains a very moderate number of channels since it uses the readout from the anode wires in a drift chamber (pitch 1 cm). Measurements were performed using current amplifiers and fast flash ADC (WASA FQDC) with cosmic rays and radioactive β-source ^{90}Sr. The gas mixtures $80\%Ar + 20\%C_2H_6$ and $90\%Ar + 5\%CO_2 + 5\%CF_4$ were investigated in more detail and low values of the drift field $\approx 40 - 60V/cm$ were found optimal for the efficient cluster registration.

References:

[1] V.Serdyuk, WASA at COSY 1st collaboration meeting, 2005, Julich

[2] V.Serdyuk, ”Tracking detectors at ANKE and WASA”, 2nd COSY-FFE Workshop, Bad Honnef, Germany, 2007

[3] http://gdd.web.cern.ch/GDD

[4] V.Serdyuk et al., 2006 Annual Report, FZJ, Julich, p.150

[5] F.Sauli, L.Ropelewski and P. Everaerts , CERN-PH-EP/2005-056, ”Ion feedback suppression in Time Projection Chamber.”

[6] J. Majewski et al., ”Development of universal set of test electronic for tracking detectors at WASA and ANKE”, 2007 Annual Report, FZJ, Julich, p.141

[7] W. Erven et al.,”DAQ QDC”, Berichte zum Datenerfassunssystem für physikalische Experimente, ZTL, FZJ, Julich, 2006

[8] W.B. Atwood et al., ”Performance of ALEPH Time Projection Chamber”, Nucl. Instr. and Meth. A306 (1991) 446

[9] B. Dolgoshein, ”Complementary particle ID:transition radiation and dE/dx relativistic rise”, Nucl. Instr. and Meth. A433 (1999) 533

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