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TPC with C-pad Read-out for Fragment Separator

R. Janik, B. Sitar, P. Strmeň, I. Szarka

Department of Nuclear Physics and Biophysics, Faculty of Mathematics, Physics and Informatics, Comenius University, 842 48 Bratislava, Slovak Republic

Abstract: Several types of Time Projection Chambers (TPC) were developed for heavy ion tracking within the last 15 years. TPCs were used for study of exotic nuclei on Fragment Separator (FRS) at GSI Darmstadt. Experiments on FRS need high precision coordinate detectors for measurements of ion tracks with little amount of material in sensitive area. In this paper a new development of TPC with C-pad read-out is described. TPCs are characterized by a high performance and reliability.

1. Introduction

The main part of the most of experiments in high energy physics are the gas coordination detectors, which are generally used to measure precisely the trajectory of particles. These detectors are pushed forward by a constant progress. An optimization of their parameters is carried out for particular experiments. In most of cases their characteristics reach their own physical limits. The measurement of complex characteristics of nuclear and sub nuclear particles' reactions leads to the utilization of special detectors in complex systems.

The experiments performed at GSI Darmstadt require the use of new detectors in the magnetic spectrometer "Fragment separator" (FRS). These detectors not only ensure an exact measurement of the ions' trajectory, but also reduce to minimum the interactions of fragments with the material in the detector. This problem was solved by the replacement of multiwire proportional chambers (MWPC) with more precise and homogeneous detectors – Time Projection Chambers (TPC) [1 2]. Such detectors were subject of the progress in our laboratory, currently they are successfully used in the experiments at GSI Darmstadt [3 9]. The parameters of these detectors prove that a new, high precision and reliable position sensitive detector was developed for detection of heavy ions. Fig. 1 shows the scheme of the Fragment separator at GSI Darmstadt and the positions, in which the TPC chambers are placed.

2. Time projection chamber

The time projection chamber is a three-dimensional tracking detector providing charge particle or ion track reconstruction together with the information about the energy losses (dE/dx). These characteristics predetermined the wide area of TPC utilization, from exploration of processes at low energy level, heavy ion physics, up to high energy particle physics.

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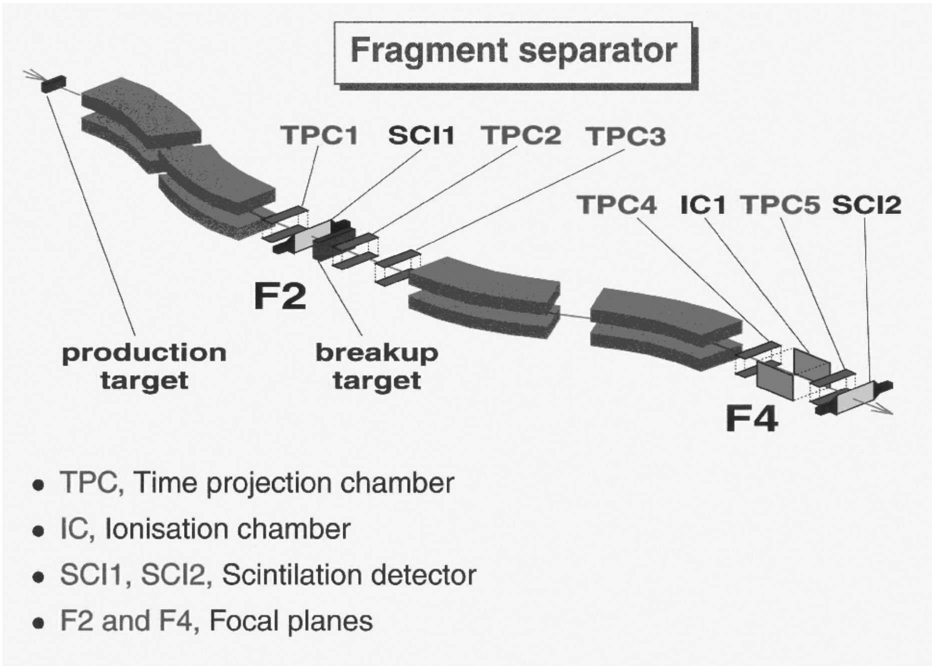

Fig. 1. Scheme of the Fragment separator (FRS) at GSI Darmstadt.

The principle of TPC operation is well known [1]. The TPC contains drift volume inside the field cage and proportional read-out chambers. When the charged particles pass through the drift volume, ionization is induced. The incurred track of electrons drifts in the homogeneous field of the drift volume towards the proportional read-out chamber, where they produce an avalanche on anodes. The position of the avalanche along the wires can be precisely measured via induced charge on cathodes. Different methods of cathode read-out are known [1]. Usually segmented cathodes strips or pads or delay lines [1 2] are used. On the other side anode signals are used for dE/dx measurements, which allow particle, or ion identification [1 2].

The drift volume of the TPC chamber filled up usually with a gas mixture P10 (Ar + + 10 % CH_4 or Ar + 10 % CO_2) is the sensitive medium for charged particles. Drift volume is surrounded by an electrical field cage. It creates homogeneous electrical field, in which the tracks composed of electrons drift towards the read-out chambers. The field cage is made of metallized Mylar strips. Each strip is attached to the resistive divider, which assures the linear drop of potential inside the field cage. In the upper part of the cage, there is a metallic cathode attached to the divider and to the negative high voltage supply; the lower part is terminated by a wire mesh, which is usually used as a gating grid over the cathode of proportional read-out chamber.

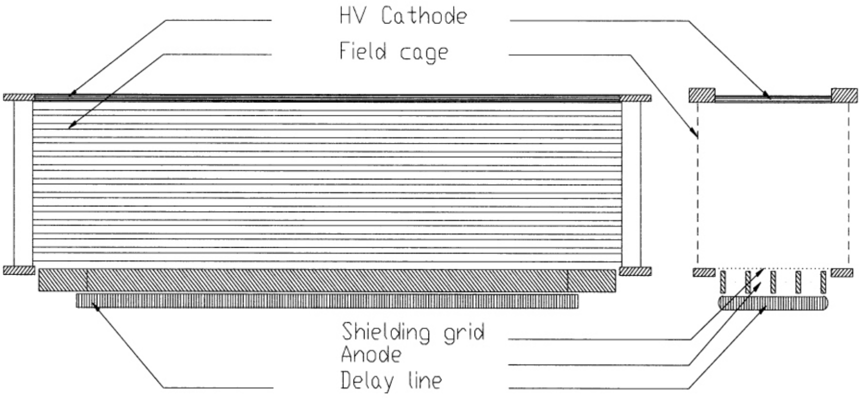

Fig. 2. Scheme of the TPC used on FRS.

3. Construction of the TPC for FRS

Fig. 2 shows the scheme of the TPC. The chamber was designed according to the requirements of the FRS. The width of sensitive area of 240 mm in the direction of "x" axis fits to the transversal dimension of FRS. The necessary height in the direction of "y" axis is determined by experimental needs and is different in different parts of FRS. Usual

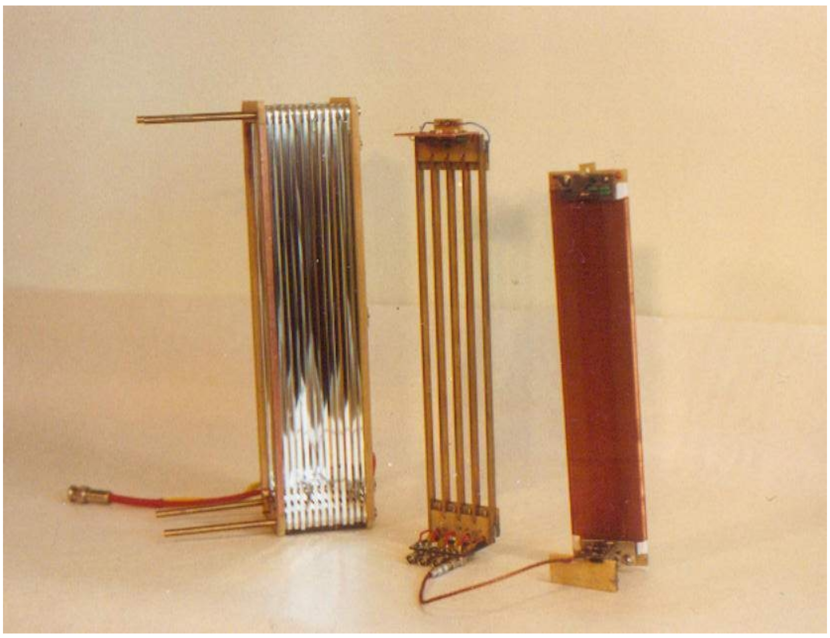

Fig. 3. View on the decomposed TPC with wound delay lines.

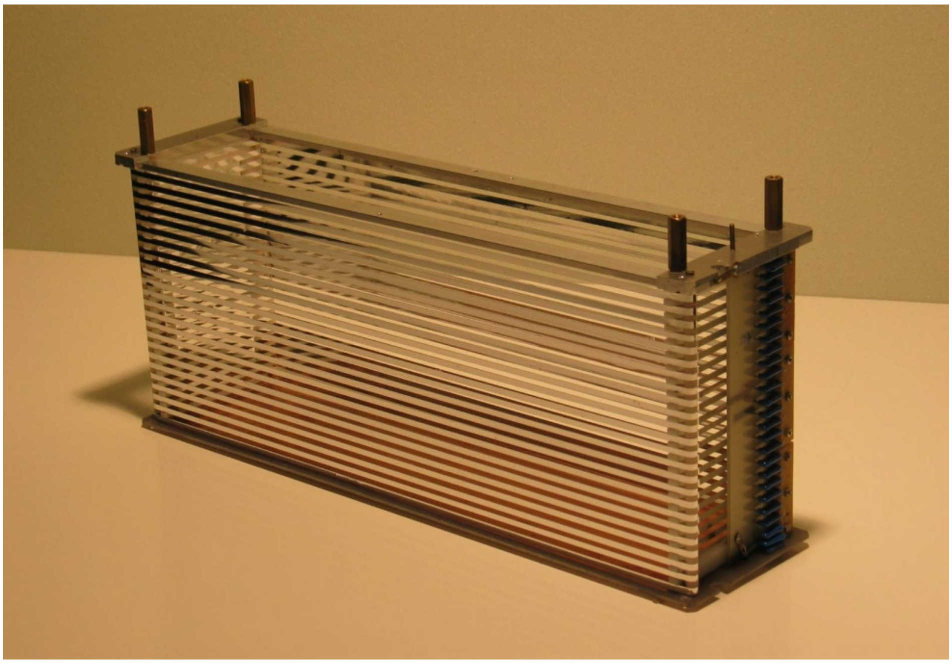

Fig. 4. View on the field cage with drift area.

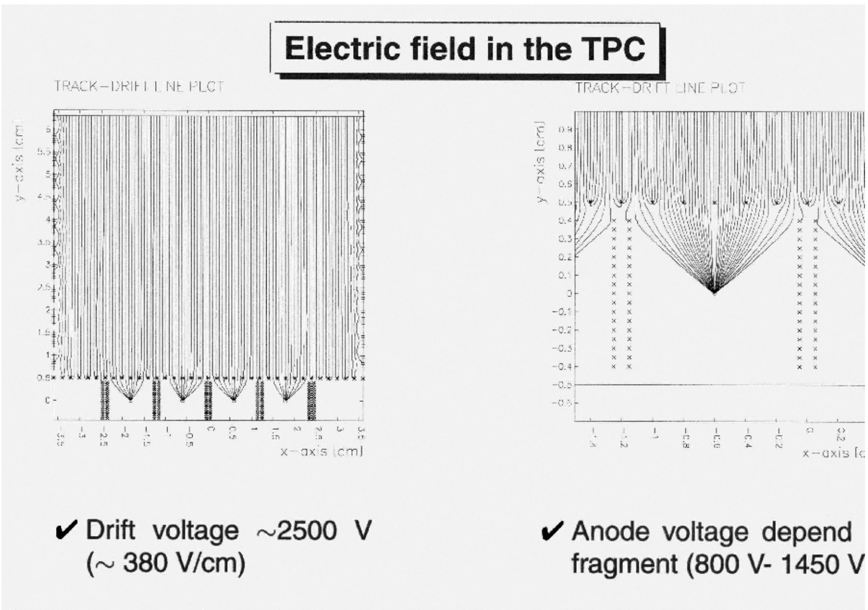

Fig. 5. Electrical field lines in the drift volume and near the anodes.

height is of 60 mm in the FRS area after secondary target in F2 focus could be 80, 100 or 120 mm. The “z” coordinate in the direction of the beam axis is determined by the position of anode wires. The TPC designed for FRS is shown in Fig. 3.

The TPC is allocated in a metallic box of 320 310 100 mm. The box is filled with a gas mixture P10 (Ar + 10 % CH_4) or Ar + 10 % CO_2. The drift volume of 300 60 60 mm with a homogeneous electrical field is determined by the field cage. A proportional read-out chamber with four anodes is located on its lover part. The electron drift time is used to measure „y“ coordinates.

Fig. 4 demonstrates the sensitive drift volume surrounded by a field cage, which is composed of Mylar strips 3 mm wide and 20 μm thick on both sides coated with 0.5 μm thick layer of aluminium. Strips are stretched on columns, which is made of Stesalit and ceramic tubes. The resistance divider is attached to the strips, which assures the linear drop of potential and resulting homogeneity of electrical field. Fig. 5 demonstrates the simulation of electrical field lines in the TPC drift volume and near the anode.

The proportional read-out chamber with four rectangular cells and anodes in their centres is situated behind the gating wire mesh. The cells have brass bars 2 mm wide and 8 mm high on theirs sides. Anodes are attached via safety resistors to the positive potential. The dimensions of the proportional read-out chamber are 280 46 15 mm.

To determine the “x” coordinate along the anode wire we used the delay line (DL) with distributed parameters, which is situated under the anodes, see Fig. 2. On the delay line an induced signal is generated as a consequence of movement of positive ions in the vicinity of anodes. The induced signal expands then from the place of induction along the delay line to both sides.

After the arrival of the signal to the output of terminated delay line, it is amplified, shaped and sent to Zero Crosser discriminator and then into the Time to Digital Converter (TDC). We are getting information from the TDC on time of arrival of the signals from anode and both ends of a delay line. From this, we can calculate the precisely x and y coordinates of the particle (ion) trajectory.

A delay line with distributed parameters is a coil wounded on a fibreglass support. Inside the support there are conductive longitudinal strips, which represent the ground, and from the other side of the support there are compensational strips tilted by 45°. These measures assure homogeneity of the delay line and decrease its dispersion [1 2]. The support is on the top and the bottom coated with a Mylar foil for insulation between the ground strips and coil. A coil made of a non-isolated copper wire is regularly wind on the support and forms the delay line with distributed parameters. At the beginning and end of the coil there are adjustment and terminating T-elements. The total delay of the line is 1.24 μs. The signal induced on the delay line is relatively small (15 % of anodes’ signal), what requires working with high gas amplification in the chamber. The high gas amplification delimits the use of the chamber at high intensity of the beam because of large space charge increase inside the read-out chamber. Therefore, it was necessary to improve the read-out system of the cathode signals.

We designed a new proportional read-out chamber with C-pad cathode. Instead of wounded delay line, we placed specially shaped strips (C shape, or U shape) under the anodes. Such shaped cathodes can have on output 50 70 % of the signal on anodes. Read-out chamber with C-pad cells were connected to an industrially produced delay line with lumped parameters from the company FLOETH. The delay of one chip is 150 ns and the delay between the strips is 15 ns. Measurements on heavy ion beams at GSI Darmstadt confirmed advantages of this solution. The TPC worked at reduced anode voltage up to the beam intensity of 300 kHz. Fig. 6 shows proportional read-out chamber with C-pads.

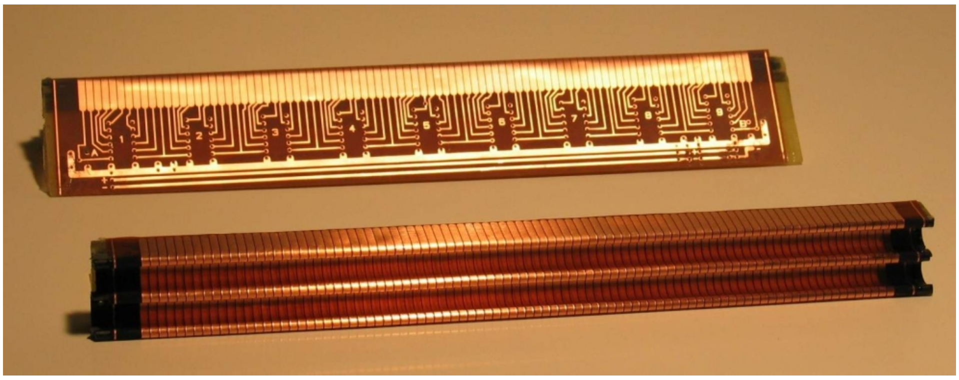

Fig. 6. View on two cell proportional read-out chambers with an integrated delay line.

In the new TPC (see Fig. 7), two double-cell read-out chambers were used. It allows to measure the y coordinate 4 times and x coordinate 2 times in each TPC, which considerably enhance the tracking accuracy.

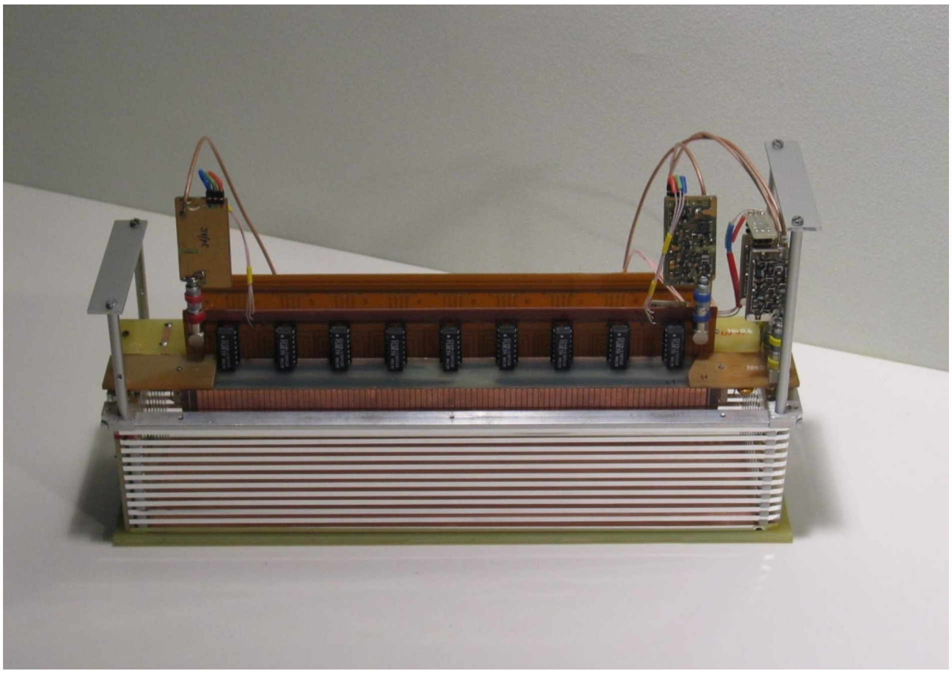

Fig. 7. View on the TPC chamber with an integrated delayed conduction.

4. Read-out electronics for the TPC

The function of read-out electronics is processing the signal from the read-out chambers. Directly inside the TPC, there are pre-amplifiers, which amplify and form the signals from anodes and cathodes. The input resistance of the pre-amplifier is adjusted to the impedance of the delay line. From the pre-amplifier output, the signal is conveyed through a coaxial cable to the input of the amplifier-shaper. From the output of the amplifier linear signals are obtained. The linear signal proceeds to the ADC. The signal for another output is conveyed to the Zero Crosser discriminator and then digital signal through twisted pairs to the TDC (blocks in NIM and CAMAC standard).

Currently, a new NIM block was especially developed containing 6 channels of electronics. In the block there are 6 channels of amplifiers, Zero Crosser discriminators and linear delay. The output signals from the block directly proceed to ADC and TDC in VME standard.

5. TPCs on Fragment Separator

It is inevitable in physical experiments on FRS to know the precise position of all detectors in the spectrometer and to carry out the calibration of TPC chambers. The centre of TPC chamber was determined by a built-in antenna at wounded delay lines. The signal induced by antenna to the delay line was registered and, when processing the physical data, it was implemented as a correction factor, designating the centre of the TPC.

Later on, an original method of absolute calibration was designed and carried out by metallic masks and plastic scintillators. Masks made of 2 mm thick and 20 mm wide brass bars were fixed on the window of the chambers in the focus point F2 of the Fragment separator. The calibration was performed by a wide beam. The ions, which passed the calibration mask, lost a part of their energy and they were removed out of the beam profile by FRS magnets. This calibration is manifested by "holes" in the beam profile demonstrated in Fig. 8.

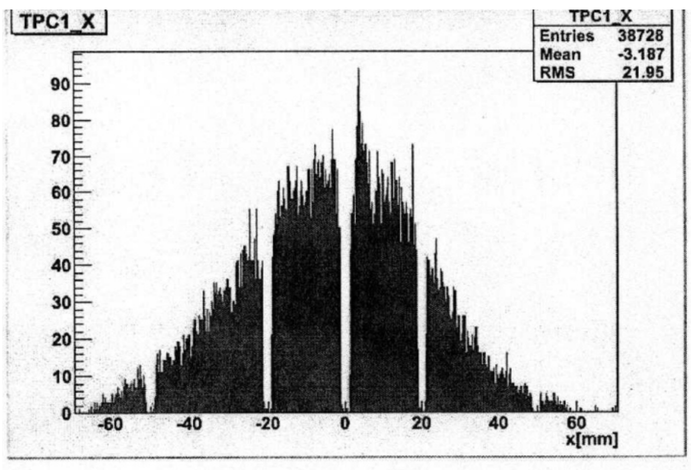

Fig. 8. Calibration of the TPC chambers by using the metallic mask.

When calibrating the chambers in the F4 focus of Fragment separator a scintillating array was used, which was formed from 1 mm thick and 10 mm wide plastic scintillators optically connected with photomultipliers. The array in a lightproof cover was inserted in front of the windows of the TPC. In this case, narrow peaks appeared in the beam profile measured by TPC, shown in Fig. 9.

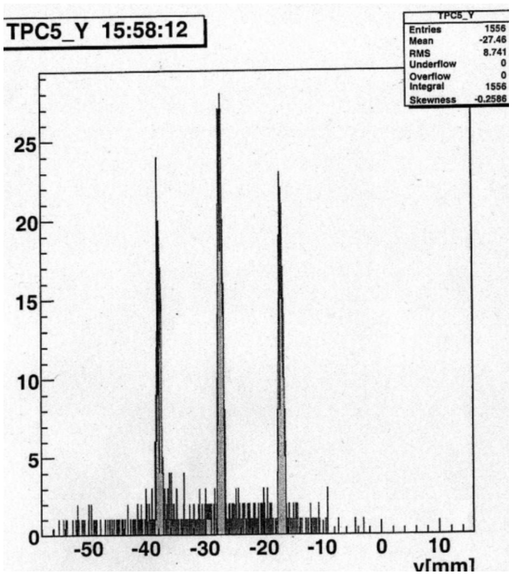

Fig. 9. Calibration of a TPC with thin plastic scintillators.

6. Efficiency and spatial resolution

When setting the optimal parameters of electronics, efficiency of ~98 % for carbon, ~97 % for boron and ~94 % for beryllium ions was reached. By using the TPC chambers we achieved a spatial resolution (r.m.s.) of $_x$ = 200 µm $_y$ = 150 µm for carbon and $_x$ = 150 µm $_y$ = 50 µm for ruthenium ions. Combining the information from five chambers (20 layers) a good ionisation resolution showing clearly separated elements form beryllium to carbon has been achieved.

7. Conclusion

Fragment separator at GSI Darmstadt is now using the described TPCs as basic coordinate detectors. They have a very good space resolution of better than 50 µm in Y direction and 100 150 µm in X direction and very little material in sensitive area. TPCs were designed to an effective registration of fragments from protons to uranium. A fast collection of data, easy handling and a minimal amount of electronic channels are considerable advantages of TPC. Using of TPCs instead of proportional chambers considerably improved momentum resolution of the FRS. TPCs were used in many experiments on study of exotic nuclei on FRS [3 9].

Acknowledgement

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