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Development of Position Sensitive Detectors in Bratislava Detector Laboratory*

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Abstract: Twenty six Inner Read-out Chambers for ALICE Time projection chamber were built in Bratislava Detector Laboratory. They were successfully tested and installed to the ALICE TPC on LHC. High precision cold forging was developed for production of aluminum C-pads. Aluminum C-pads could be produced in large quantities for cathode read-out of large TPCs. Several types of Time Projection Chambers (TPC) were developed for heavy ion tracking. TPCs are used for study of exotic nuclei on Fragment Separator at GSI Darmstadt. Specially designed high quality read-out electronics has been developed for TPC detectors. A large Beam Profile Monitor (BPM) was designed and produced. The BPM using the low pressure gas system enabled to measure beam profiles in a wide range of beam intensities, up to high fluxes of heavy ions.

1. Read-out chambers for ALICE TPC at CERN LHC

Bratislava group produced 26 Inner Read-out Chambers (IROC) (Fig. 1) for ALICE Time projection chamber (TPC). TPC ALICE contains 36 IROC chambers. For the production of IROC chambers clean rooms were built in Bratislava Detector Laboratory. They contain 4 closed rooms with different level of cleanness. The entrance to the clean rooms was allowed only in special clean overall. All operations with open IROCs were performed only in the clean rooms. For the final cleaning pressurized nitrogen was used.

Equipment for the production and testing of 26 IROCs was built at Bratislava laboratory from high quality components. The equipment consists of:

- Mounting table
- High precision co-ordinate measuring equipment for IROC assembling
- Winding machine
- Equipment for measuring and testing of IROCs
- Material for IROC chambers
- Gases and radioactive sources for tests.

Precise marble mounting table 80 60 10 cm with metallic support was used for IROC assembly. High precision, three dimensional co-ordinate wire positioning device with the motor driven movement and precision of 0.005 mm was assembled in the clean rooms. Computer controlled semiautomatic linear motor driven measuring equipment with the precision of 0.005 mm was built. It allowed fast measurements of wire positions. Typically measurement of 200 wires lasted about 1 hour.

A winding machine was also built in our laboratory. A special device assuring equal wire tension was developed. Special tools were developed for homogenous application of

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*) *Dedicated to Ing. Rudolf Janik on the occasion of his 70th anniversary.*

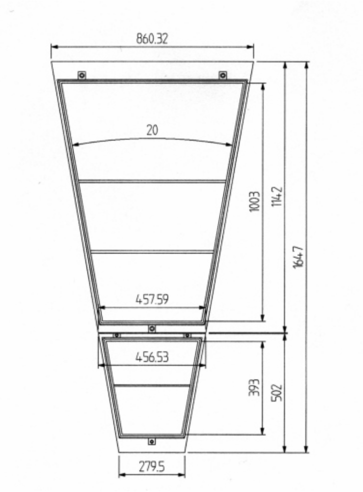

Fig. 1. Inner read-out chamber for ALICE TPC.

Fig. 2. View on the test bench with the test chamber for IROC testing.

the glue to the fibreglass bars. A tension of each wire was measured after gluing on the chamber frame. As a result of these measures wire tension differences were within few percent around the designed value.

For testing of IROC characteristics several (15 15 cm) small prototypes ROC (SP ROC) were produced and delivered to GSI for testing on the particle (ion) beams. Several characteristics of SP ROC were measured in Bratislava. Bratislava group also produced a full size prototype of IROC.

Twenty six IROC chambers were tested (Fig. 2) according to the agreed procedure at Bratislava laboratory, by electronics comprising channels of front end electronics and ADC in Camac standard. For faster and more precise testing according to the TPCC protocol Alice TPC front end card was delivered from TPC collaboration to Bratislava laboratory. For IROCs testing a special test box was used at Bratislava detector laboratory filed with ALICE TPC gas mixture Ne + 10% CO_2 + 5% N_2. The tests comprised the following procedures:

- Long term tests of IROC 26 - raw data, O_2 content, temperature, resolution and anode current
- Leak tests - O_2 content in tested modules was 4–5 ppm for gas flow rate 15 l/hour
- Uncorrected and corrected anode current for 1300 V on anodes
- Measurements of dark current - lower than 50 pA
- ^{55}Fe peak position and amplitude resolution 15–18%
- Count rate 30 kHz was used
- Uncorrected and corrected gas gain curve for the flow 15 l/hour
- Position scan with ^{55}Fe source
- Resistance between wire planes measured for HV = 400 V, temperature 26 C, humidity 38%.

All 26 IROC chambers were tested in Bratislava with good parameters. They were sent to GSI Darmstadt and later to CERN. Bratislava group took part in the installation of IROC chambers to the TPC ALICE.

2. High precision cold forging of aluminum C-pads

TPCs often use cathode pad read-out for second co-ordinate measurement. The cathode to anode signal (C/A) ratio for planar pads is usually of 0.2–0.4. It is necessary for proper signal to noise ratio to use higher gas gain, which cause higher production of positive ions near the anode. It is evident that higher C/A ratio will be generally advantageous. We developed a TPC read-out with C-pads, which allows to increase C/A ratio up to 0.7. There was an idea to use ring cathodes, or C-pads for TPC Alice, where number of pads exceeded 500 000. We developed a technology of cold forging for mass production of aluminum C-pads.

For TPC geometry C-pads were designed with dimensions 6 6 2 mm with ±0.02 mm production and positioning precision, which should allow the maximum signal fluctuation along the anode wire to be 2%. High precision cold forging was developed for production of aluminum Cpads. We learned by simulation and also in praxis that it is very difficult to forge a high precision C-pad by one stroke. C-pad production has a sequence of several steps. In the first step a precisely defined portion of aluminum is cut. In the second stoke a U-pad, higher then the final one, is produced. In the next step the height of the pad is cut with the angle of 15 . The last step is bending of the C-pad arms to the inner radius of 5 mm. All those procedures are made in one semi-automat, form which ready-to-use C-pads are falling to the container. Each C-pad has two holes on the bottom side, which allows its positioning to the board with a precision of ±0.02 mm.

We produced several thousands of aluminum C-pads by high precision cold forging technology and several cathode read-out systems were produced and tested. Precise positioning was made by pins in the board and holes in pads. The bottom part of C-pad was gold plated by sputtering and then fixed to the board by conductive glue. Tests showed that aluminum C-pads could be produced in large quantities and they are good quality elements for cathode read-out of large TPCs.

3. Time Projection Chambers for Fragment separator in GSI Darmstadt

Within last 15 years, our group developed several types of TPC for heavy ion tracking [1–3]. TPCs are used for study of exotic nuclei on Fragment Separator (FRS) at GSI Darmstadt [4]. Experiments on FRS need high precision coordinate detectors for measurements of ion tracks with little amount of material in the sensitive area. In this paper a development of TPC with Cpad read-out is described.

Time Projection Chamber is a true two-dimensional detector for track reconstruction. It allows also particle (ion) identification by multiple (*dE*/*dx*) measurement in the ADC. The sensitive part of TPC is a field cage created by 30 m thick aluminized Mylar strips 3 mm wide stretched with 4 mm pitch. This assured minimum amount of material in the sensitive area of the TPC. The TPC is filed by proper very clean gas mixture (usually Ar + 10% CH_4, or Ar + 10% CO_2) in atmospheric pressure (Fig. 3).

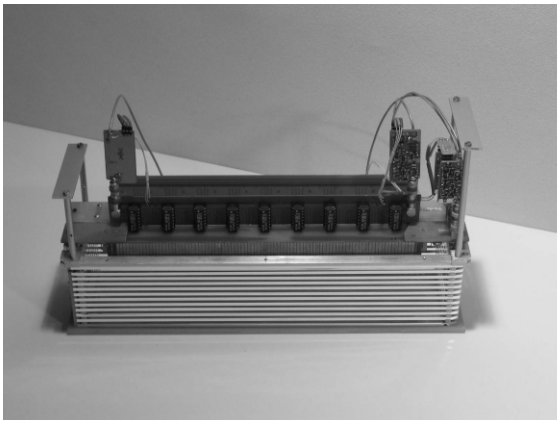

Fig. 3. Inner part of the TPC used for heavy ion tracking at FRS.

Electrons from the ion tracks are drifting along the homogenous electric field to the proportional chamber with several anode wires. The vertical (Y) coordinate is calculated from the measured electron drift time from track to the anode. The horizontal (X) coordinate is calculated from induced signal spread through the delay line, which is a part of the cathode. The START signal for Time to digital converter (TDC) is provided by the trigger signal from FRS. The STOP signal is coming to TDC form anodes, or both ends of delay lines.

Two types of delay lines were used in TPC. Earlier wounded delay lines with distributed parameters (produced by our group) were used. The field cage can have a different height of the sensitive area of 6, 8, 10, or 12 cm and the width of 24 cm. The proportional chamber consists of 4 proportional cells 12 mm wide with anodes in the centre of each of them. The upper cathode is in form of a wire mesh and the lower one is formed by a wounded delay line 45 mm wide underneath of all four proportional cells. This type of TPC provides measurements of 4 Y coordinates and 1 X coordinate. It provides also four (dE/dx) measurements. Signals form the anodes and both ends of delay lines are processed in read-out electronics and read out by ADC and TDC. The newly developed TPCs use C-pad cathodes and integrated delay lines.

This approach allows increase of the cathode signal amplitude from 25% up to 65% of the anode signal. As a result of such improvement, it is possible to decrease gas gain and the TPC can work in ion fluxes with 3 times higher intensity. With integrated delay lines with 15 ns delay per cathode wire (2 mm pitch), spatial resolution of the order of 100 m in X coordinate can be reached. TPC with C-pads provides measurements of 4 Y coordinates and 2 X coordinates. It provides also four (dE/dx) measurements.

Fragment separator at GSI Darmstadt is now using described TPCs as the basic coordinate detectors. They have a very good space resolution of better than 40 m in Y direction and 90–150 m in X direction and very little material in sensitive area. Use of TPCs instead of proportional chambers considerably improved the momentum resolution of the FRS. TPCs were used in many experiments on study of exotic nuclei on FRS [5–9].

3.1. Read-out electronics for TPC

Specially designed high quality read-out electronics has been developed for TPC detectors. Standard CAMAC electronics modules were used. Use of high intensity ion beams forced development of specially designed electronics for TPC, which integrates all modules to one NIM block with 6 channels of integrated electronics in a NIM standard. The scheme of such a block is shown in Fig. 4.

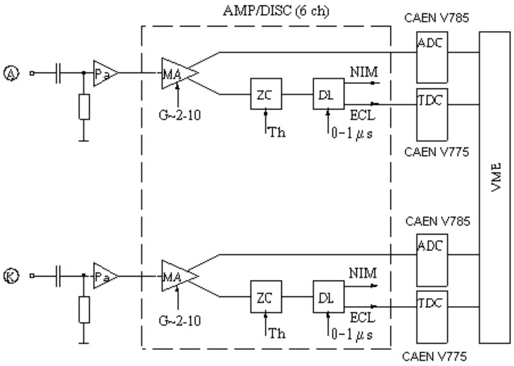

Fig. 4. Block scheme of two electronic channels for the TPC, Pa – preamplifier, MA – main amplifier-shaper, ZC – Zero crosser, DL – Delay line, ADC – Amplitude to digital Converter, TDC – Time to digital Converter.

The module contains in each channel:

- Linear amplifier-shaper (MA) with adjustable gain of 4–30 and maximum output signal amplitude of 8 V
- Zero-crosser (ZC) discriminator with timing on the signal maximum with adjustable threshold 50 mV–1 V
- Digital delay (DL) up to 1 s
- NIM-ECL adapter.

A new block was used instead of several conventional modules, which considerably improved and simplified the whole read-out electronics. The block is inserted between the outputs of preamplifiers mounted on the TPC and Amplitude to digital converter (ADC) and Time to digital converter (TDC) in VME standard. The electronics fulfils all demands for highly sophisticated co-ordinate detectors - TPC. Seven new electronic blocks were used instead of several conventional modules in many experiments on study of exotic nuclei on FRS [5–9]. The electronics is characterized by high performance and reliability.

4. Development of Beam Profile Monitors for high intensity ion beams at FRS

A large Beam Profile Monitor (BPM) prototype was designed and produced (Fig. 5) in a form of a proportional chamber. The BPM volume was filled with Ar + 10% CO_2 gas using the low pressure gas system, which allowed varying the gas pressures from 1 to 1 000 mbar. This enables the BPM to measure beam profiles in a wide range of beam intensities, up to highest fluxes of ions. The active area of the BPM is 200 100 mm^2. The BPM has a modular structure with a basic module of 100 100 mm^2. The BPM can contain many of such modules, so a large BPM could be constructed. The prototype BPM is equipped with 3 integrated delay lines which are directly connected to the cathode wires for X and Y position measurements simultaneously. Adjustable preamplifiers have been constructed with a gain factor of 0.3 V/pC. This allows use of the BPM to measure the beam profile of fast extracted ion beams. New integrated electronics containing shaping amplifiers, zero crossers and Flash ADC was developed and used in the tests.

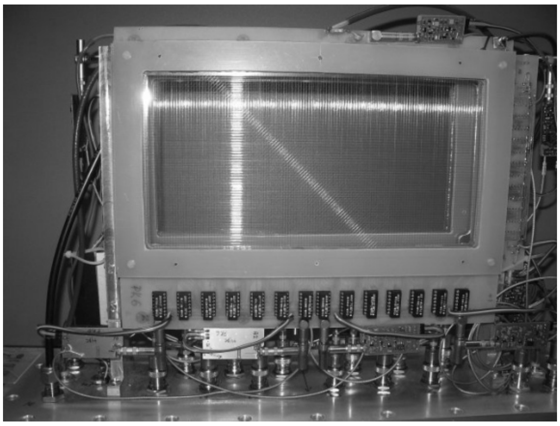

Fig. 5. Beam Profile Monitor with front-end electronics.

A beam tests experiment using the Beam Profile Monitor prototype has been performed at FRS. The BPM was placed at the second focal plane (S2) of the FRS. Accelerator SIS18 was operated in the fast-extraction mode using a ^{12}C beam with energies of 200–400 MeV/u. The detector response has been investigated at a gas pressure between 3–950 mbar increasing the beam intensity gradually from 10^7 up to 1.6 10^9 ions per spill, which was the highest available intensity from SIS 18 in S2 plane of the FRS. No saturation effects were observed indicating still considerable reserves for even higher beam intensities. The spill length of the beam was 300 ns. A new electronics with fast signal shaping (adjustable preamplifiers, delays etc.) has been tested and worked reliably. For the digitalization a fast electronics was used, based on the Flash ADC SIS3301. The trigger was given by the time signal from the BPM anodes. The anode signals were used also for longitudinal beam profile measurements.

The new electronics based on Flash ADCs built for this purpose worked reliably. Off-line analysis of the test run showed that the prototype beam profile monitor worked according to the designed parameters.

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