Test of TPC readout electronics with the UNIMOCS detector.

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1. Introduction

The next big project in particle physics after the LHC is supposed to be the International Linear Collider (ILC). Besides the work on the accelerator, research and design program on four different detector concepts is ongoing.

The FLC-TPC group at DESY is involved in various topics of the R&D work for the Large Detector Concept (LDC) [1]. This concept includes a Time Projection Chamber (TPC) as the main particle tracker. The work in the group includes testing and studies of gas amplification structures like Gas Electron Multipliers (GEM), the construction of prototypes for the TPC field cage, the development of reconstruction and analysis software as well as the construction and testing of the read-out electronics.

A TPC consists of a large cylindrical gas volume, immersed in a homogenous electric field generated by applying a high voltage between the cathode and the anode. A charged particle traversing the TPC gas volume ionizes the gas and liberates electron-ion pairs. Under the action of the homogeneous electric field the electrons drift toward the anode, where a two dimensional readout is built. These electrons are then amplified using a Micro Pattern Gaseous Detector (MPGD), for example Gas Electron Multipliers (GEM).

On the way to ILC TPC the Large Prototype TPC (LP TPC) is being built in the framework of the EUDET project [2]. Also within this project, a new TPC readout electronics based on a Time-to-Digital Converter (TDC) is being designed. In order to perform stand-alone tests of this readout electronics, a simple GEM detector – UNIMOCS [3] has been prepared. During the preparation of the UNIMOCS detector, tests with the existing electronics were performed, which are the subject of this paper.

2. UNIMOCS

The detector has a modular design and allows to test different components/configurations. In the current configuration the detector has the following features:

- ✓ drift length 3 cm
- ✓ no field cage
- ✓ triple GEM setup
- ✓ pad-plane with 112 pads of size 2.54 mm x 14 mm

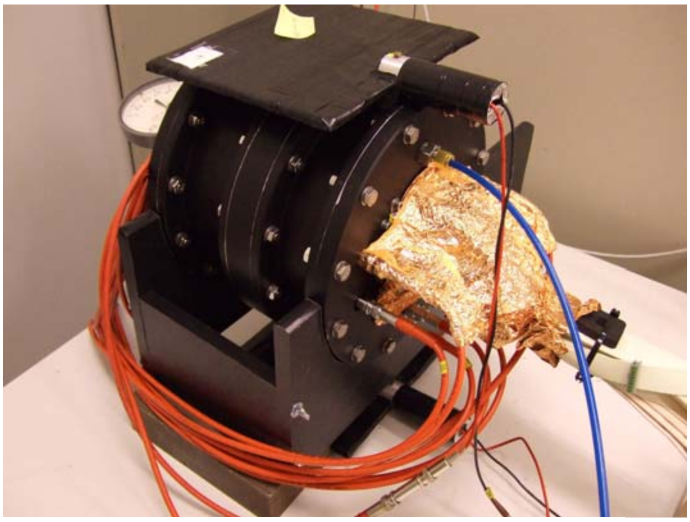

***Figure 1**. The UNIMOCS detector*

The absence of the field cage simplifies the design, but introduces electric field inhomogeneities. For the drift length of 3 cm these inhomogeneities are of no great importance. Other operating parameters: cathode voltage: 3 kV, gas Ar (93%) CH_4 (5%) CO_2 (2%).

The measurement of the Z-coordinate is performed by the measurement of the drift time of the electrons from primary ionization in the gas:

$$Z = V_{drift} * T_{drift} ,$$

where V_{drift} is the drift velocity of the electrons from primary ionization in the gas, T_{drift} is the drift time of the electrons. The drift time is defined as a time interval between an external trigger signal and the time of arrival of the electrons of the primary ionization at the pad-plane. With V_{drift} = 3.5cm/μs [4], the maximal drift time T_{drift} (max) is 0.9μs.

3. Readout electronics based on TDC

In order to perform the tests 6 ASDQ boards (see Figure 2) were installed at the UNIMOCS. A single ASDQ board comprises 16 channels of amplifier, shaper and discriminator. The discriminator of the ASDQ works as charge-to-time converter. For more details on the ASDQ see [5] and links herein.

With the help of a receiver (see later) signals from ASDQ boards are translated into ECL level signals required by the TDC.

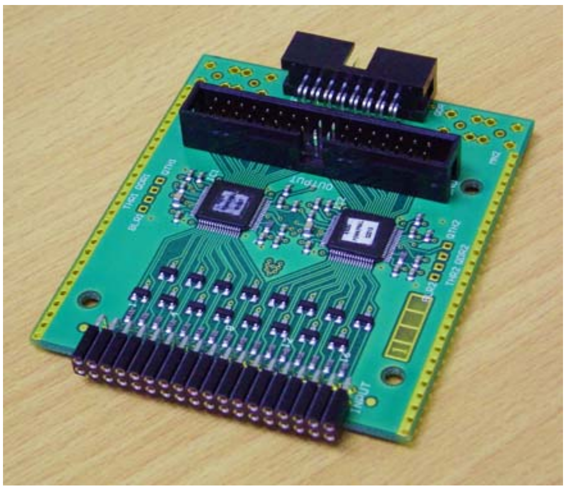

***Figure 2**. 16 channel Front-End Electronics board based on ASDQ*

Digitization of the signals in time is done with the help of a commercial 128 channel multi-hit VME TDC v767. This TDC has 0.78 ns time bin size and 800 μs time measurement range. An event buffer of 256 cells allows multiple signals to be recorded for every channel. Both the front and the rear edge of the signal on the input of the TDC are recorded, thus making it possible to reconstruct the pulse width of signals from the ASDQ.

The multi-purpose TDC allows data readout in different modes, for example using an external trigger signal (trigger mode) or data-driven readout (continuous storage mode) [6], [7]. Data stored in the buffer of the TDC are transferred to a VME CPU, which runs under the Real-Time OS Lynx.

4. Test of the TPC readout electronics

4.1. Test of the data acquisition system

Before the test of the TDC-based readout electronics, the data acquisition system has been tested with a pulse generator (see Figure 3). A single channel of an ASDQ board was connected to the pulse generator via a charge injector. A voltage step from the pulse generator is converted to charge (Q= C*U). In this test the signals from the ASDQ output were recorded with the help of a digital oscilloscope. The trigger signal from the pulse generator was used as a trigger signal for the TDC. An ASDQ Service Module (ASDQsm) provides power (±3V) for the ASDQ boards and translates the trigger signal level to the one required by the TDC.

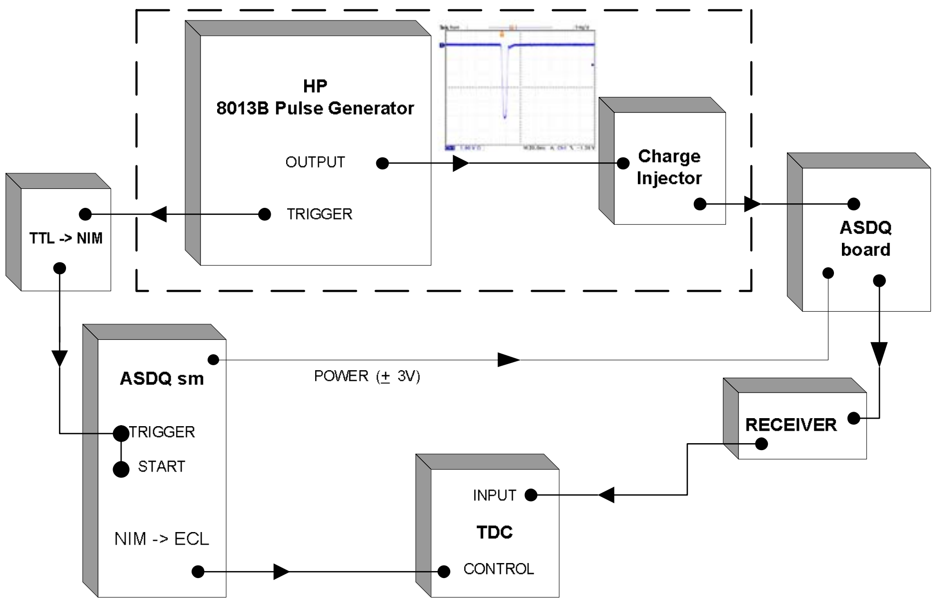

Figure 3*. Test of the data acquisition system with a pulse generator*

Using the VME access library a simple program of was written. The program reads data from the TDC (front and rear edges), correctly reconstructs the pulse width and displays the result on screen. It was found that the pulse width is in agreement with the one measured by the oscilloscope.

4.2.1. Test of TPC readout electronics with the UNIMOCS detector.

In this test the UNIMOCS is used on a cosmic ray setup: two scintillation counters were installed below and above the detector. The high voltage of the counters was setup in such a way, that the counting rates were approximately equal. The coincidence signal from both counters is the trigger signal for the data acquisition system. The high voltage of the GEM's resistor divider [3] was set to 2560V. The cathode voltage was 3000V. The threshold on the ASDQ boards was set to 0.27V.

A new data acquisition program was written. The program sets up the parameters of the TDC (reset, mode of operation, readout of front & rear edges, disable noisy channels (64, 79, 80, 95)), reads out data and writes it to a file. Together with the data, the trigger signal is digitized by the TDC and written to the same file.

A ready-made event display program [4] is used to display data from the file, see example of an event on Figure 4. The program shows hits[1] (black dots) and the trigger signal (red bars).

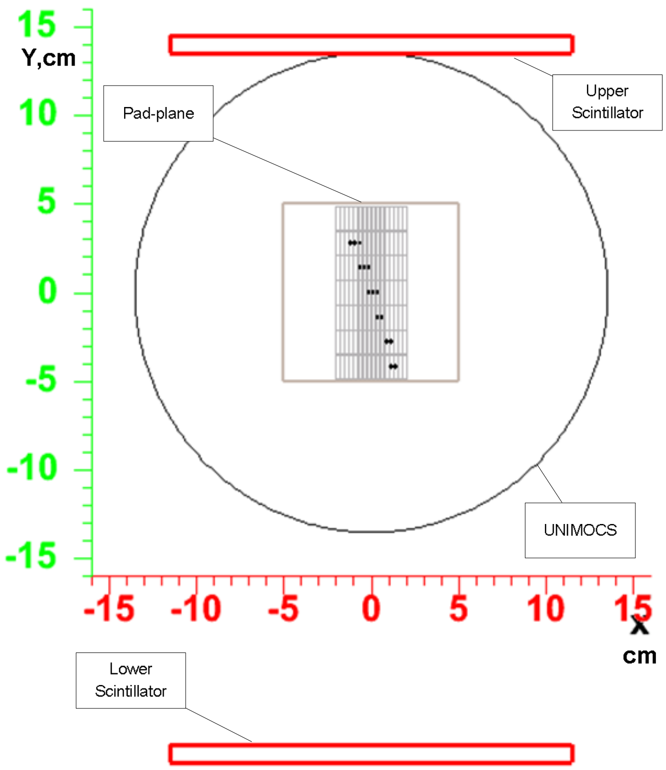

***Figure 4**. Example of a cosmic ray event*

[1] A single time record from a channel is called a hit. Only front edges are considered.

During data taking (4 days), the operation of the GEM setup was found to be stable enough - 7 trips of the GEM voltage were observed. A full track reconstruction will be done on the next stage of the test [3].

In addition, an increased number of noise signals was observed on the side columns (outer pads on the left and right) of the pad-plane, Figure 4. This fact is taken into account in the new design ("Barcelona") of the pad-plane.

4.2.2. Test of a software selection of track-candidates (triggerless data readout)

A new method of data readout was tested. This time, the TDC mode was set to "continuous storage", where the readout is initiated by the incoming data itself and not by the coincidence signal from counters. The coincidence signal from the counters is still recorded and can be used in a data analysis, if desired. In this mode the definition of event lost its old meaning. Continuous data stream from the detector contains information on tracks having passed both counters (and therefore a data record on coincidence signal is present in the TDC data stream) and those which did not cross the counters. Thus track-candidates have to be chosen in software.

A selection algorithm has been developed and the event display program was modified. The algorithm works in the following way:

- ✓ The first hit is used to set a search window in time. The time window equals the maximal drift time (0.9μs)
- ✓ All following hits form a "track-candidate".

Two selected track-candidates are shown on Figure 5a and 5b. The full dataset contains many

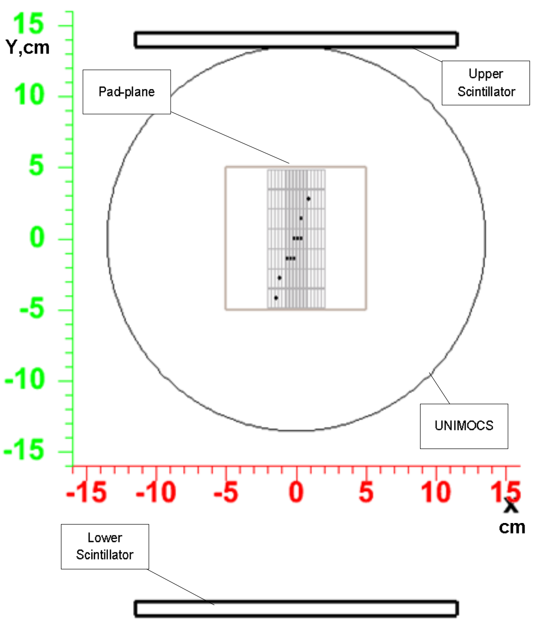

Figure 5a. *Example of a track-candidate which pass the counters*

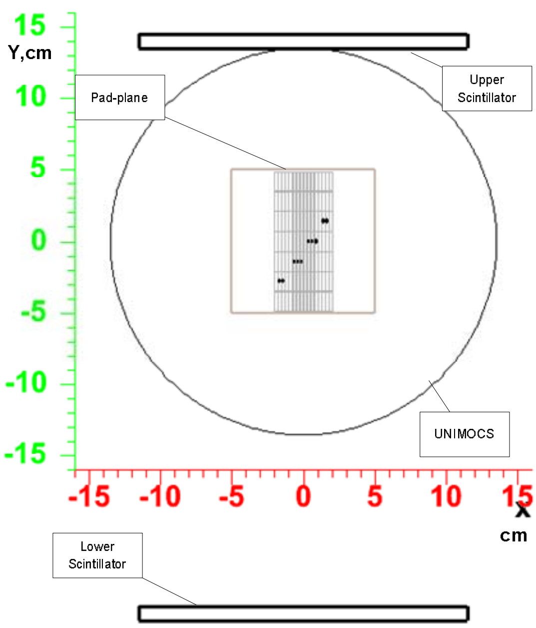

Figure 5b. *Example of a track-candidate which did not pass the counters*

noisy track-candidates. Good tracks can be selected with the help of a track reconstruction program. The track-candidate on Figure 5a has if a records on coincidence signal (indicated by black color of the counters), but one can see that the track would cross both counters. This can be because of an inefficiency of the coincidence unit circuit. The track-candidate on Figure 5b does not cross both counters and would be missed in the case if TPC readout electronics work in the trigger mode. However, since time information from the coincidence signal is missing, absolute measurement of the arrival time (and so z-coordinate) is not available. Therefore, in the continuous storage mode of the TDC-based readout electronics, one can collect a larger number of tracks.

5. Conclusion

Tests of the readout electronics were performed with the UNIMOCS detector. A good performance of the UNIMOCS' GEM setup was observed: within 4 days of operation only 7 trips of the GEM voltage occurred. A new data acquisition program was used and an advanced method of data readout was tested. Complete data analysis will be done later [3].

One of the improvements of the method of track-candidate selection can require the minimum number of hits equal 4, in order to diminish the influence of noise and speed up the reconstruction of good track-candidates. Complementary, in the new design of the pad-plane additional dummy pads on the outer edges have been implemented. In future, new TPC readout electronics (under development) will be tested again with the UNIMOCS detector.

References

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[7] J. Christiansen, "32-channel TDC with on-chip buffering and trigger matching", Given at 3rd Workshop on Electronics for LHC Experiments, London, England, 22-26 Sep 1997