

OPERATING MCP DETECTORS AT CRYOGENIC TEMPERATURES*

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Abstract

At present, a low energy electrostatic storage ring operating at cryogenic temperatures down to 2 K (CSR) is being build up at the Max-Planck-Institut für Kernphysik (MPIK) in Heidelberg [1]. Both, beam diagnostics and experiments rely on the use of position sensitive microchannel plate (MCP) detectors equipped with phosphor screens or delay line anodes. Since little is known about the performance of these detector types in a cryogenic environment a test chamber was built to investigate their properties. A MCP detector with delay line read out was successfully tested at temperatures as low as 25 K. In this contribution the results of these tests as well as possible applications of the detector are presented.

INTRODUCTION

One of the key experimental installations in the cryogenic storage ring will be a reaction microscope. The implementation of a reaction microscope allows for the kinematically complete study of ion-atoms collision. In these experiments the ion beam is intersected with a cold supersonic jet target. Both recoil ions and electrons created during the collision are guided to position sensitive detectors via homogeneous electric and magnetic fields. From the position of impact on the detector and the time of flight the initial momenta of the charged particles can be determined [2]. Until recently reaction microscope studies were only performed in a single shot mode, where the projectiles are dumped behind the target region. This limits the accessible count rate, especially in collision experiments with rare ions or investigation of unlikely reaction channels. In December 2006, for the first time, an in-ring reaction microscope has been operated in the experimental storage ring ESR at GSI [3], although at much higher energies of up to 400 MeV/u.

The reaction microscope, as well as many beam diagnostic elements relies on detectors which are capable of measuring single or multiple incident particles in combination with highly resolved position readout. Usually microchannel plates are used as electron multipliers combined with delay line anodes or phosphor screens. Since the reactions rates in the reaction microscope are usually quite low, to ensure the unambiguous reconstruction of the particle momentum, delay line anodes are favoured, which combine a good position sensitivity with a low dead time of only a few nanoseconds. Up to now, there is only few data available about the operation of MCP detectors at cryogenic

temperatures [3,4]. None of these detector tests have been conducted using a delay line anode read out. To test the suitability of MCPs as well as delay line anodes at temperatures around 20 K, a test chamber was built up. In this chamber, the complete detector was cooled down and its detection sensitivity was determined.

POSITION SENSITIVE DETECTOR

The detector consists of a chevron type MCP with 40 mm diameter. During the tests, a set of two standard BURLE MCP as well as Burle enhanced dynamic range (EDR) MCPs was installed to investigate differences in their behaviour. Both MCPs have 25 μm pore size at 8° bias angle with an aspect ratio of 60:1. At room temperature the resistance of the MCPs was measured to 41 M Ω and 31 M Ω (EDR), respectively, using a source meter. Typical gain factors for these kinds of channel plates are 10^7 . Behind the set of MCPs a position sensitive delay line anode was mounted consisting of two pairs of detection wires wrapped upon a holder plate. The electron cloud created in the MCP after particle impact is accelerated to the delay line hitting the detection wires. The travelling times of the generated fast negative signal to both ends of a wire is measured. By calculating the time difference for both x and y direction, the position of the particle impact on the MCP surface can be determined with an accuracy of better than 0.1 mm [5].

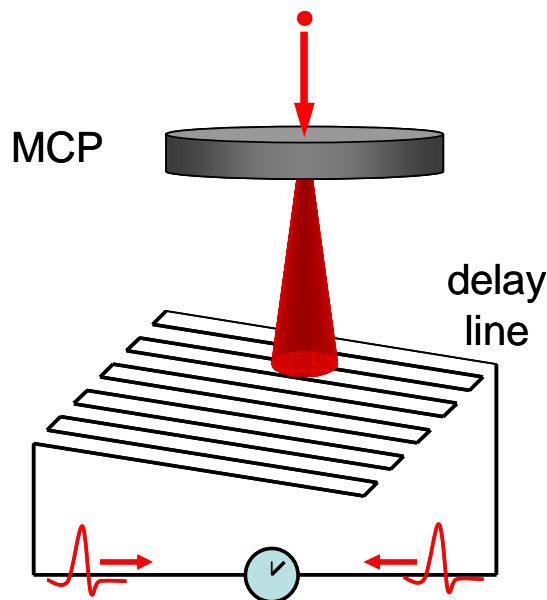


Fig.1: Schematic drawing of a delay line detector

While the time difference is related to the position of the incident particle, the sum of the two times must be a constant mirroring the total length of the delay line wire.

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This time sum is used filtering out useless events. A schematic drawing of a delay line detector read out is depicted in figure 1.

COLD TEST CHAMBER

To test the detector at well determined conditions a dedicated test chamber was built up. To reach the lowest temperatures possible, the detector was mounted on a cryo cooler. The cooling power was delivered by a Somitomo RDK-408E coldhead with two stages, capable of delivering a cooling power of 31 W at 40 K on the first stage and 1 W at 4.2 K on the second stage. The whole setup was installed in a vacuum chamber operating at an insulating vacuum of 10^{-8} mbar to prevent heat transfer via convection. A CAD drawing of the whole setup inside the vacuum chamber is shown in figure 2. The remaining heat transfer is given by means of the thermal conductivity of the connecting wires of the detector and thermal radiation from the outer wall of the vacuum chamber, which stays on room temperature. To reduce the heat load from thermal radiation from the room temperature environment, the first stage of the cold head was connected to a thermal shield made of pure copper. To reduce the thermal load even further, the whole shield was wrapped into multilayer insulation. The detector itself was mounted in a copper box which was connected to the second stage of the cold head by the use of a strip of pure copper. To measure the particular temperatures during the tests several temperature sensors were installed.

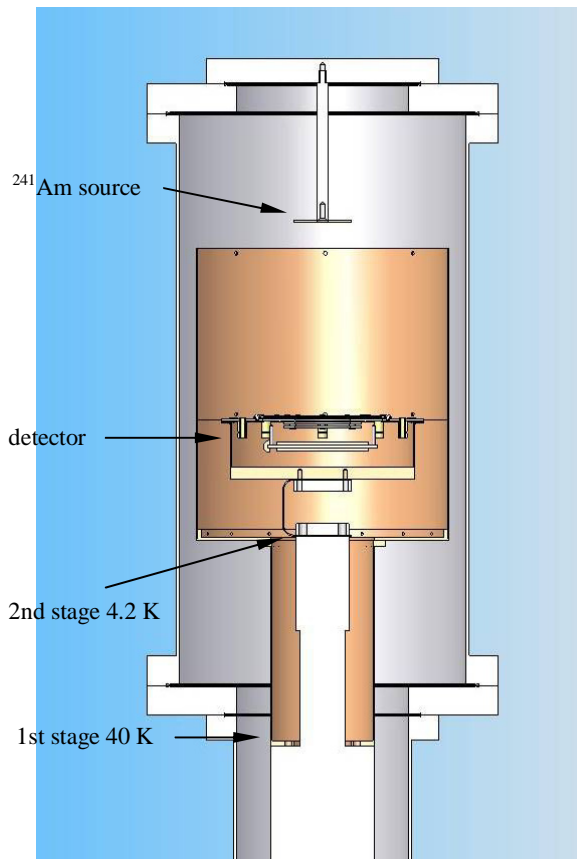


Fig.2: CAD drawing of cryogenic test chamber

The shield temperature was measured with a PT 1000 platinum resistor, which can be used to temperatures as low as 30 K. The temperature of the second stage particularly on the inside of the detector was measured with calibrated DT 630 silicone diodes, which are commercially available as temperature sensors. The DT 630 diodes feature an operational range down to 1.2 K. Directly on the cold head the lowest temperature achieved was 6.5 K. The temperature of the detector was measured on the backside of the MCP stack to 25 K. The thermal coupling of the detector to the coldhead is done through the mount of the detector with the temperature sensor sitting behind the MCP stack detector.

During the cooling phase the resistance of the MCP was measured over the whole temperature range of observation. Previous publications [3,4] already showed that the resistance should increase by several orders of magnitude. This behaviour was confirmed, although the absolute values vary in comparison to other publications.

The EDR type MCPs provide a higher dynamic range. They can withstand higher count rates while still being sensitive for single particle detection. They also show a slightly lower resistance at room temperature, here 31 M Ω . In comparison, the resistance of the normal 40 mm MCPs is 41 M Ω . During the cooling down the resistance of the EDR MCPs showed a similar behaviour as the standard MCPs. In the case of the EDR MCPs, the resistance increases at higher temperatures, but with a slightly lower slope (see figure 3). The higher resistance could lead to a decreased gain for higher count rates, since the individual channels of the MCP are not fully charged.

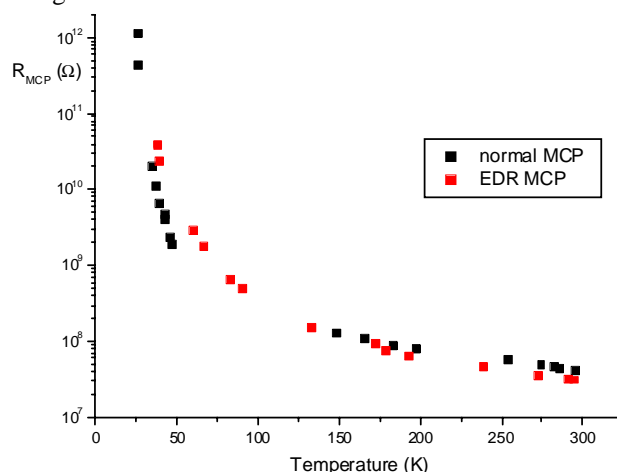


Fig.3: Resistance of the chevron MCP stack as a function of temperature

To test the detection efficiency of the detector, a small ^{241}Am source with an activity of 37 kBq was placed on a flange opposite to the detector mounting. Emitted alpha particles were detected. Taking the solid angle and the open detector area into account, a count rate of approximately 300 events per second was anticipated and also reached in the test setup.

DATA ACQUISITION

The read out of the detector was realised using an ACQIRIS DAQ system consisting of three flash ADC digitizers with 4 channels and a sampling rate of 2 GSamples/sec per channel. For the data acquisition and analysis the AGAT code developed at the IKF Frankfurt was used. For the calculation of the detector position only the timing of the signals and a reference time signal is needed. As a reference the signal of the MCP itself was used. Nevertheless, the digitizers provide the whole pulse information, which can give some additional insight on the behaviour of the detector. For example, even the absolute pulse height and width of each individual signal can be investigated and logged over the whole temperature range. This feature can also help to further decrease the detector dead time, since even events with overlapping signals can be distinguished using an appropriate algorithm [6]. To further characterize the properties of the detector test spectra can be defined to identify nonlinear behaviour along the direction of the wires. As an example figure 4 shows typical signals from both the MCP and the delay lines, as they were acquired during the tests.

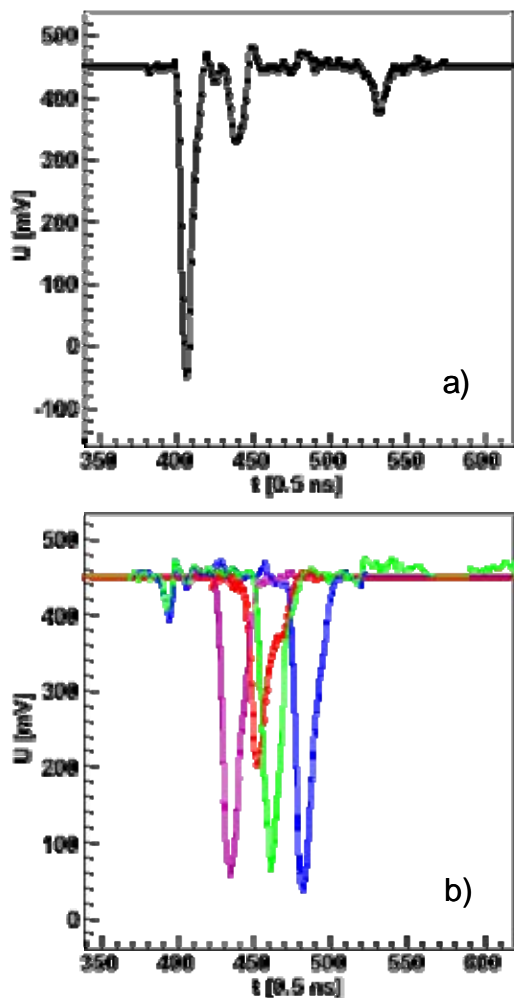


Fig.4: Typical signal shapes for MCP (a) and delay line signals (b)

SUMMARY

In this paper the test results with a MCP detector equipped with a delay line readout operated at temperatures down to 25 K were presented. The tests showed that the resistance of the MCP stack increases by five orders of magnitude over the whole temperature range of observation. For the count rates reached with the used source, the MCP as well as the delay line readout works well even at the lowest achieved temperatures of 25 K. This strongly encourages the use of this type of detectors in the cryogenic temperature range.

In the next step the detector will be mounted in the cryogenic test facility (CTF), recently being built up at the MPIK. The CTF acts as a prototype machine for the CSR, which will be built in the near future. In the CTF, the whole experimental vacuum chamber is cooled down to a temperature of 1.8 K. In this setup the temperature distribution in the detector is avoided, since the whole detector mount is cooled. The detector will then be used as a projectile detector for trapping experiments in the Zaifman trap being installed inside the CTF.

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