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Results of in-beam tests of an MCP-based vacuum sector prototype of the T0/centrality detector for ALICE

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Abstract

We report on results of efficiency tests for MIPs and timing resolution studies obtained with different layouts of micro-channel plate (MCP) detector prototypes at CERN PS test beams. The detector is composed of an MCP stack and multipad readout anodes integrated with a passive isochronal summator. Several types of setups were tested, including MCPs with different gain. Also, a very first test of the Micro Sphere Plates detector was performed. The performance of fast electronics including Double Threshold Discriminators and a fast multiplicity discriminator for short 2 ns signals was studied. Currently, the best experimental results for MCP detectors show 75 ps timing resolution obtained at 75% efficiency for the registration of a single muon. We expect further enhancements, mostly through improvements in the fast electronics.

1. Introduction

A Micro-Channel Plate (MCP) disk detector system with integrated isochronal signal readout and precise timing capabilities is considered as one of the options for the ALICE pre-trigger T0/centrality detector. MCPs are a well-known device for the registration of charged particles due to their excellent timing properties (20–50 ps), high internal gain (10^3–10^6), fine granularity (5–10 μm), and high radiation hardness. In the present design for ALICE, the very short signal produced by the detector includes the information from the whole MCP disk (or half the disk, depending on the final design). This is achieved by using multichannel isochronal passive summators. These summators are integrated into the microelectronics design of the detector readout [3–5]. The leading edge of the MCP disk output signal carries the precise timing information relevant for central collisions of

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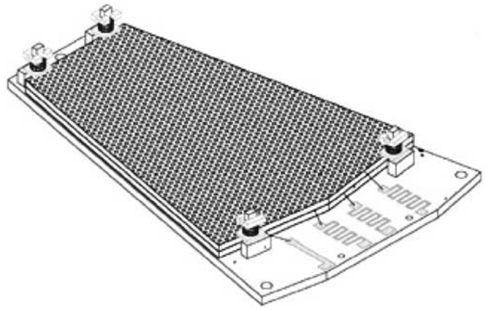

Fig. 1. Compact MCP sector (22.5°) setup. Length of MCP is 60 mm.

relativistic heavy ions. The use of MCPs for the detection of minimum ionizing particles and the development of a fast pre-trigger detector for ALICE require the development of large area MCP arrays which are embedded into a thin-walled vacuum chamber equipped with a compact getter pump ensuring long-term operation [1–3]. We have developed practical technological solutions which satisfy the requirements for compact, high-vacuum (10^{-6}), hermetically closed portable chambers with MCP detectors and a precise isochronal readout system [6]. Long-term operation tests of miniature Ti-getter pumps and the technology of sector chamber hermetization have proved successful over the last 15 months. Here we present results of in-beam tests of MCP sector prototypes which were produced by using previously developed technologies [1–3,6]. Fig. 1.

2. Tests

Sector detectors of approximately 20 cm^2 sensitive area are composed of a micro-channel plates stack and multipad readout anodes integrated with a microelectronics designed UHF passive summator. An independent, hermetized, thin-walled (200 μm) stainless steel vacuum chamber equipped with a Ti-getter pump was used for one of the MCP sector prototypes [1–3,6]. Other setups included commercially available high-gain MCPs tested inside an actively pumped vacuum chamber. We also carried out the very first tests of the MIPs registration efficiency of a new kind of high-gain secondary electron emission detector based on MicroSphere Plates (MSPs)[1]. Parameters of the tested detectors are summarized in Table 1.

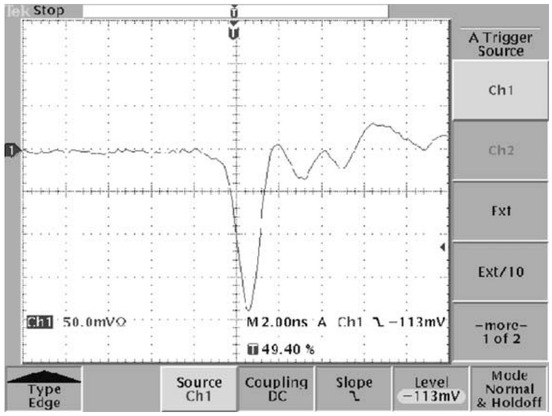

Fig. 2. Signal obtained from the MCP sector detector after the fast preamplifier.

The initial in-lab studies were to define the efficiency of gamma-radiation registration and the time resolution of the detector by using a coincidence method with a radioactive ^{60}Co source. Two scintillation detectors were studied in coincidence with each other and with the MCP detector. The results for efficiency and time resolution were obtained from the coincidence peaks. An efficiency value of 0.16% for gamma-radiation detection was determined for the MCP sector prototype, which is in line with what is needed for future applications.

The in-beam tests of the detector prototypes and electronics were started at the CERN GIF area (150 GeV/c muons) and then continued at the T10 area of the CERN PS beams (7.5 GeV/c). The detector to be tested was positioned between 4 fast scintillation counters which determined the charged particle trajectories and were included in the trigger. The detector output signal passed the fast (1 GHz), low-noise preamplifiers and was then sent (see Fig. 2) to the fast timing electronics. The dynamic range of the signals applied was from 30 mV to 1.5 V. The T10 test trigger provided a very precise (software) determination of the particle's arrival time at the level of 30 ps (sigma).

[1] Micro Sphere Plates, Technical Information.

Table 1
Some parameters of MCP prototype detectors

No.	Tested items	Gain per plate	Thickness/ch. diam. (μm)
1	Russ. 2 MCPs + summator (OSMCP-R-2)	10^3	700/12
2	Russ. 2 MCPs + Summator(HGMCP-R-2)	10^4	500/10
3	Europ. 2 MCPs (HGMCP-E-2)	10^4	500/25
4	Europ. 3 MCPs (HGMCP-E-3)	10^4	500/25
5	MSP-1 plate [9]	10^8	800/–

The fast electronics which was tested with the MCP's 2 ns signals included:

- fast low-noise preamps (Granit) [1] (up to 0.7–1.0 GHz range),
- a fast LED-type multiplicity discriminator (MD) [8],
- timing discriminators: standard CFD (ORTEC-934) 200 MHz, Phillips Scientific, PicoTiming (ORTEC-9307) and Double Threshold Discriminator (DTD) [7].

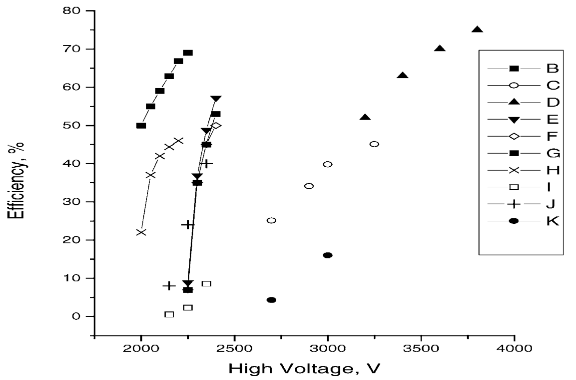

Fig. 3. Efficiency for MIPS registration vs. high voltage for different setups, see text.

3. Results and discussion

Some results of the in-beam measurements of MIPs registration efficiency vs. HV obtained for different types of MCP detectors are shown in Fig. 3.

The definition of the data points in Fig. 3 is given below:

- B — 2 Sector MCPs (Minsk, high gain, 12 μm) + Summator + Phil. Scientif. CFD, October 1999, GIF, muons 150 GeV/c,
- C — 2 High Gain MCPs (HGMCP-E-2, 25 μm) + PicoTiming Discriminator, May 2000, PS/T10 area,
- D — 3 High Gain MCPs (HGMCP-E-3, 25 μm) + PicoTiming Discriminator, May 2000, PS/T10 area,
- E — 2 Sector MCPs (Minsk, 12 μm) October 1999, Sample 3, CERN-GIF, muons 150 GeV/c,
- F — 2 Sector MCPs (Minsk, 12 μm) in vacuum chamber (OSMCP), October 1999,
- G — 2 Sector MCPs (Minsk, 12 μm) in vacuum chamber + Phil. Scientific. CFD, GIF, October 1999,
- H — 2 High Gain MCPs (HGMCP-R-2, GOI, Russia, 10 μm) + DTD or Pico, May 2000, PS/T10,
- I — 2 Sector MCPs (Minsk, 12 μm) in vacuum chamber (OSMCP) + ORTEC-934 CFD, May 2000, PS/T10,
- J — 2 Sector MCPs (Minsk, 12 μm) in vacuum chamber (OSMCP) + DTD, May 2000, PS/T10,
- K — 1 MSP, 800 μ + PicoTiming Discriminator, May 2000, PS/T10.

The best results were achieved for the high-gain sector chevron MCP setup (data "B") due to the following factors: (i) high intrinsic gain of the MCPs used (10^4); (ii) small channel diameter (12 μ) and (iii) large MCP plates thickness (800 μm). Results are very close to those reached previously [9–12], pointing to the problem of using adequate fast, low-noise electronics to handle a wide dynamic range of 2 ns signals. Various fast signal discriminators were studied. E.g., a standard ORTEC-934 (200 MHz) CFD was found to be less then 25% efficient for 2 ns signals. Comparable results in efficiency were achieved by using PicoTiming and a DTD (see data "H" in Fig. 2). Nevertheless, it was only the DTD that provided both efficiency and timing for the whole wide spectrum of signal amplitudes. A Multiplicity Discriminator (MD) was designed [8] to handle short 2 ns input signals ranging from 0 to 2.5 V. Programmable threshold settings with an estimated resolution of 8 bits and an output signal latency of 15 ns were used. The minimum input signal charge to trigger the MD over the threshold setting was calculated from a preliminary laboratory study to be about 0.26 pC. The MD was tested and proved to be functional with real short MCP signals. Measurements of amplitudes vs. threshold settings confirmed its usefulness as a simple multiplicity pre-trigger device. Besides, it was proved to be also reasonably good in timing (a resolution of about 120 ps was obtained with the MD).

The high intrinsic gain of the MCPs or MSP used (10^4–10^8) was found to be not the only condition for obtaining a high efficiency for the registration of minimum ionizing particles. The minimum channel diameter was also found to be essential for a high efficiency for MIPs registration. Very first measurements were made for a new device called the MSP detector (see data "K" on Fig. 3). A single plate of 800 μm thickness (gain 10^8) was placed in vacuum in the same test-beam geometry as the MCPs. The plate was biased at 3000 V. The readout was performed over the anode located at a distance of 500 μm from the plate. An ORTEC-9307 PicoTiming discriminator was used after a fast ORTEC-9306 preamplifier. 16% efficiency was achieved as a first result. This confirms the initial conclusion about the important role of a high internal gain in combination with a surface emitting a large number of secondary electrons. This internal feature is expected to be present in MCPs with smaller-diameter channels. In this case, a single MIP passing through the plate crosses several channels, which leads to a higher efficiency of registration. More detailed laboratory studies of these factors are needed. Currently the best experimental results show 75 ps timing resolution obtained at 75% efficiency for the registration of a single MIP. Assuming 75 ps and 75% for a single MIP, simulations performed for two large area MCP isochronal disks for OO, ArAr, KrKr, SnSn and PbPb collisions yield a timing resolution below 10 ps (if adequate electronics is provided) and 100% trigger efficiency, respectively.

4. Conclusions

1. The long-term performance of MCP detectors has been proved for a thin-walled (200 μ) hermetised vacuum chamber since October 1999.
2. The high efficiency for the registration of minimum ionizing particles by an MCP-based detector which had been measured previously was confirmed for the registration of muons of 150 and of 7.5 GeV/c momentum. It was found to be not less than 75% when adequate electronics was used.
3. Various fast signal discriminators including DTD for the short 2 ns signals from the MCP detector were studied. It was found that only the DTD is capable of providing both efficiency and timing for the whole wide spectrum of amplitudes.
4. Currently, the best experimental results obtained for MCP detectors show 75 ps timing resolution obtained at 75% efficiency for the registration of a single MIP.
5. Assuming 75 ps and 75% for a single MIP, a simulation performed for two large-area isochronal MCP disks for OO, ArAr, KrKr, SnSn and PbPb collisions yields a timing resolution below 10 ps (if adequate electronics is provided) and 100% trigger efficiency, respectively.

Acknowledgements

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