Краткие сообщения ОИЯИ №4[50]-91 *JINR Rapid Communications No.4[50]-91*
УДК 539.1.07

MICROCHANNEL PLATES AS A DETECTOR FOR 800 MeV/c CHARGED PIONS AND PROTONS

F.F.Valiev[1], G.A.Feofilov[1], A.P.Tsvinev, A.A.Baldin[2], Yu.K.Gavrilov[2]

The initial results of the first measurements of the efficiency of the registration of high energy charged pions and protons by a tandem of microchannel plates (MCPs) are reported to be not less than (80±10)%. A new application of the delay line as a direct readout MCP's anode in combination with strips is discussed. The proposals for a new type of a vertex detector that includes all MCP advantages are made.

The investigation has been performed at the Laboratory of High Energies, JINR.

Микроканальные пластины как детектор заряженных пионов и протонов с импульсом 800 МэВ/с

Ф.Ф.Валиев и др.

Приводятся начальные результаты исследований эффективности регистрации высокоэнергетических заряженных пионов и протонов сборкой из двух микроканальных пластин (МКП), полученная величина составляет (80± 10)% и может быть улучшена. Обсуждается также новая координатная система съема информации с МКП, включающая плоскую линию задержки непосредственно в качестве регистрирующего анода МКП в комбинации со стрипами. Выдвигаются предложения по созданию вершинного детектора нового типа, включающего все достоинства МКП.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Introduction

Microchannel plates (MCPs) are widely used now for the detection of various sorts of radiations (see, f.e./1-6/) due to their well-known properties:

---

[1] Leningrad State University.

[2] Institute for Nuclear Research, Acad. Sci. USSR.

- high counting rates
- low self noise
- good performance in the magnetic field
- high radiation resistivity
- small amount of matter introduced to the way of the particle
- possibility of an application in various position sensitive detectors.

However, the detection of the moderately relativistic particles by the microchannel plates was not studied yet.

Thus the main purpose of this work was to show the principal possibility of using the MCP as a detector of high energy particles. Besides we are making the proposals for a new type of position-sensitive detector that can provide precisely both time signal and two space coordinates of the track interacting the MCP's surface.

2. Detector description

We used standard MCPs that had the diameter of 34 mm, thickness of 400 μm and the channels density of 10^6 1/cm^2 .The plates were made of SiO_2 PbO with the density of 3.89 g/cm^3. Channels are 10 μm in diameter and have the wall thickness of 2 μm. The bias angle of the channel axis with respect to the front surface normal is 10°.

Two MCPs mounted in a shevron setup/2/ with an interplate distance of 0.5 mm were placed into a small vacuum chamber together with the coordinate sensitive readout anode (see fig.1). Chamber has provided $3\cdot10^{-5}$ mm Hg and had two thin Al (1 mm) front and rear windows.

The MCPs were operated by a high voltage ~1000 V each. We also used a small accelerating potential between the plates and between the second plate and the readout anode (~100 V). The high voltage adjustment was done to obtain the characteristic saturation effect/3, 4/ for the MCP's pulse spectrum (see fig.2).

We used two types of readout anodes: i) 0.8 mm strips and ii) a combination of a delay line and strips. In contrast to/5/ we used a flat delay line directly as a readout anode. Those two systems of readout anodes were used for two sorts of measurements: i) for the efficiency measurements, ii) for the test coordinate resolution measurements of a new coordinate sensitive anode.

The MCP output pulses after charge sensitive preamplifiers were sent to the fast amplifiers (or to the analog filter amplifier and ADC). We used standard CAMAC electronics for constant fraction discrimination, coincidences, TAC and ADC with KK009 crate controller and IBM-compatible PRAVETZ.

3. The efficiency of MCPs for the detection of high energy pions and protons

The measurements have been performed at the Laboratory of High Energies, JINR.

The layout of the experiment for the MCPs efficiency measurements is shown schematically in fig.1.

Two MCPs placed into a small vacuum chamber were sandwiched between two plastic scintillators (see fig.1). The whole setup was exposed to the pion and proton beams that had the intensity of up to 10^6 l/s.

The efficiency was derived as a ratio of TAC's line intensity to the whole number of two plastic coincidence (i.e., the ratio of TAC to CC counts) with the account of the geometry of the setup. During the efficiency measurements all strips were used together with a single preamplifier.

It is a known fact that the so-called geometrical efficiency of MCPs for the strongly interacting particles cannot be higher than 70%. This is due to the surface dead region of the walls edges for those particles.

As to the high energy particle passing through the plate and crossing several channels the electron avalanche may start at any place of track's intersection with the cylinder surface of any crossed channel. Thus in our case we can expect the increase of the efficiency compared to that of strongly interacting particles due to the mentioned argument.

The effective thickness seen by a minimum ionizing particle (MIP) passing through one MCP described above is $\sim 90\ \mu$m, that leads/7/ to a mean value of ionization losses estimated for Si of 34 keV, which may result in $\sim 10^4$ pairs produced along the track in a single MCP. It's clear that only the fraction of channel surface created electrons may work. The same argumentation may be valid for δ-electrons also. Nevertheless an MCP seems to be a good target-converter for MIPs, playing additionally the role of electron multiplier. The only thing remains to be done — it is not to lose the weak electron signal corresponding to the deep regions of MCP, e.i. one has to make an extra amplification by using a second MCP (or to use the MCP with higher gain).

Results of the efficiency measurements together with the MCP self-noise are shown in the Table. The measurements were done for two threshold levels in the MCP's CFD (they are marked by arrows in fig.2). The results of the table are averaged on two series of measurements done with pure proton beam and with a 50/50 mixture of pions and protons having 800 MeV/c. It was justified by the absence (within the limits of accuracy of the present experiment) of any significant amplitude spectra dependence on the type of the detected particles.

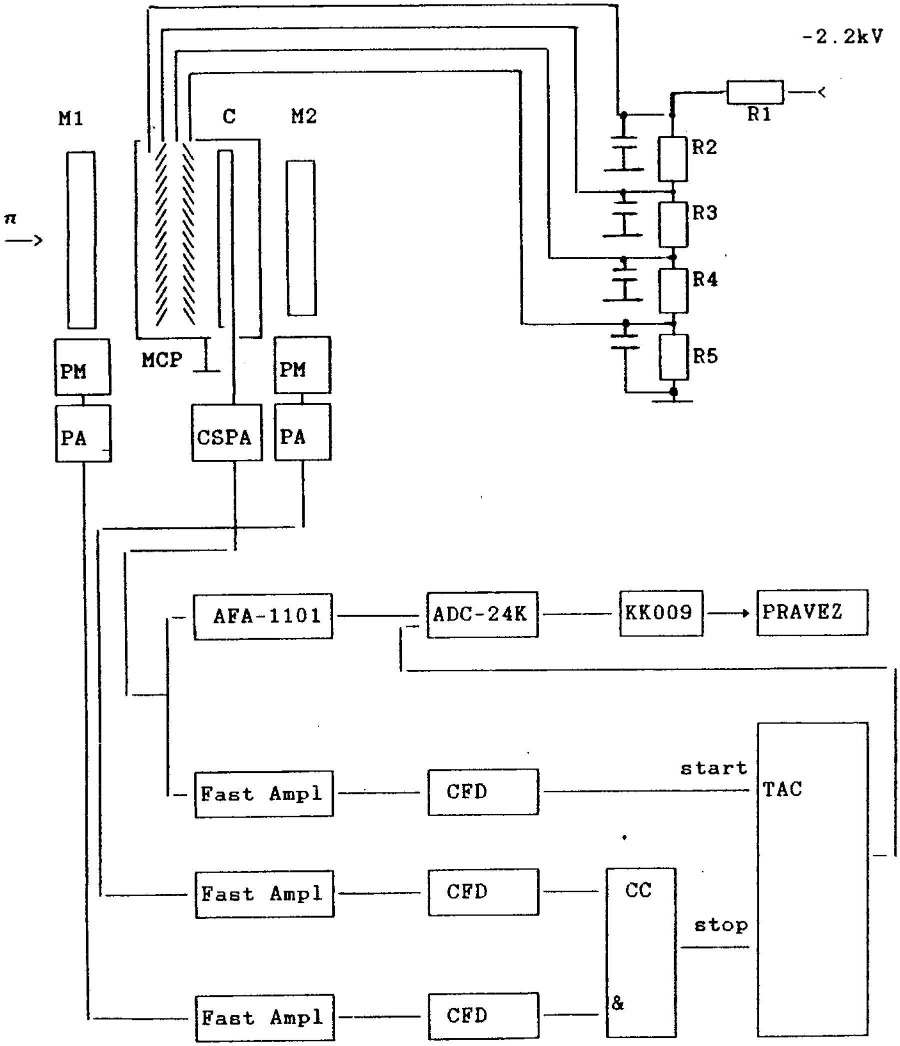

Fig. 1. General layout of the experiment with the MCP detector. MCP — a tandem of microchannel plates; R1 — R5 — high voltage divider; C — strips; M1, M2 — plastic scintillators; PM — photomultiplier; PA — preamplifier; CSPA — charge sensitive PA; AFA — analog filter amplifier; CFD — constant fraction discriminator; CC — coincidences scheme; TAC — time to amplitude converter; ADC — analog-digital converter; (delays and counters are not shown).

The dependence of the efficiency on the CFD threshold is quite obvious from fig. 2. Thus we can conclude that i) the saturation MCP's effect is not exhausted and it is possible to increase the bump

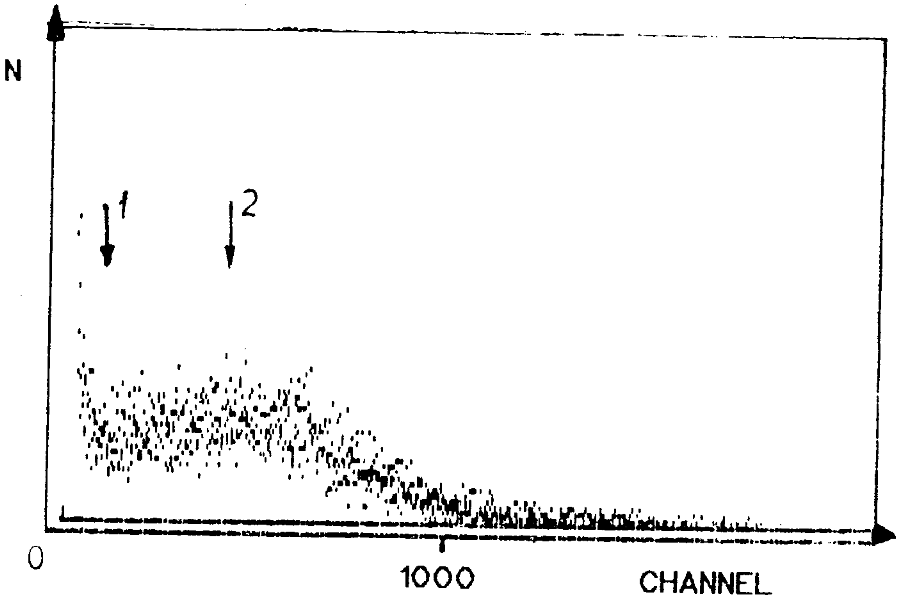

Fig.2. Amplitude spectrum of signals from MCP detector obtained for 800 MeV/c pions. Arrows correspond to the threshold levels in MCP strip channel (1 — channel No.70, 2 — ch.No.520).

Table. The efficiency of the MCP's tandem for the detection of 800 MeV/c pions and protons

CFD threshold (ADC channel No)	Efficiency, %	MCP's self-noise, $cm^{-2}s^{-1}$
520	45±5	0.390±0.004
70	80±10	0.684±0.007

intensity (fig.2) by more careful high voltage tuning, because the exponential soft part of the MCP's amplitude spectrum corresponds to the useful events (not to the electronics background), ii) additional CFD threshold adjustment may be done without the deterioration of signal/noise ratio. The last argument is based on the close similarity of the MCP self-noise amplitude spectrum to that of detected particles.

The accuracy of the efficiency measurements in the run was determined by the accuracy of geometry overlap estimation for MCPs and plastic scintillators.

4. Proposals for a new type vertex detector

The concept is to use MCPs for the detection of high energy particles playing a double role of a very effective target-converter and electron multiplier. This provides i) the possibility of using lesser amounts of matter and to minimize a multiple scattering as compared to silicon strip detectors, ii) placing the detector close to the target in the vacuum beam pipe, iii) using all other benefits of MCP as a detector (f.e. good behavior in high magnetic fields/8/).

The best vertex detectors can provide up to 2 μm spatial resolution but at the price of a great number of strips or pixels together with sophisticated electrons used for the signals readout (see, f.e./10, 11/). More essential is the fact that the usually applied method of charge dissection for two dimensional readout (see, f.e./10/) is good for precise coordinate measurements but it takes additional time and is not suitable for fast triggering application.

For a number of physical studies planned for the investigations/9/ at the universal 4π-spectrometer AMPIR a vertex detector is needed capable to provide both timing and at least one coordinate measurements directly, so it could be used in the first trigger.

The first promising results obtained for the efficiency of MCPs for the detection of high energy pions and protons and the advantage of using an independent coordinate sensitive readout anode allow us to propose a new readout unit based on a combination of a flat delay line and usual set of strips situated inside. Figure 3 shows the example of a possible setup.

This proposal combines the following advantages: i) the usual set of strips provides the precise time signal and one coordinate measurement in a usual way, this information may be sufficient for the first trigger, ii) the use of a flat continuous delay line directly as a readout anode gives a possibility of considerable simplification of the second coordinate measurements.

We have tested the described coordinate sensitive unit for Z-coordinate resolution using a Po^{210} α-source and a special mask. We used a flat 30 mm x 100 mm delay line (τ = 300 ns) made of 50 μm wire. Longitudinal strips of 0.8 mm x 100 mm were situated inside the delay line. We used the same electronics as in the previous run (fig.1).

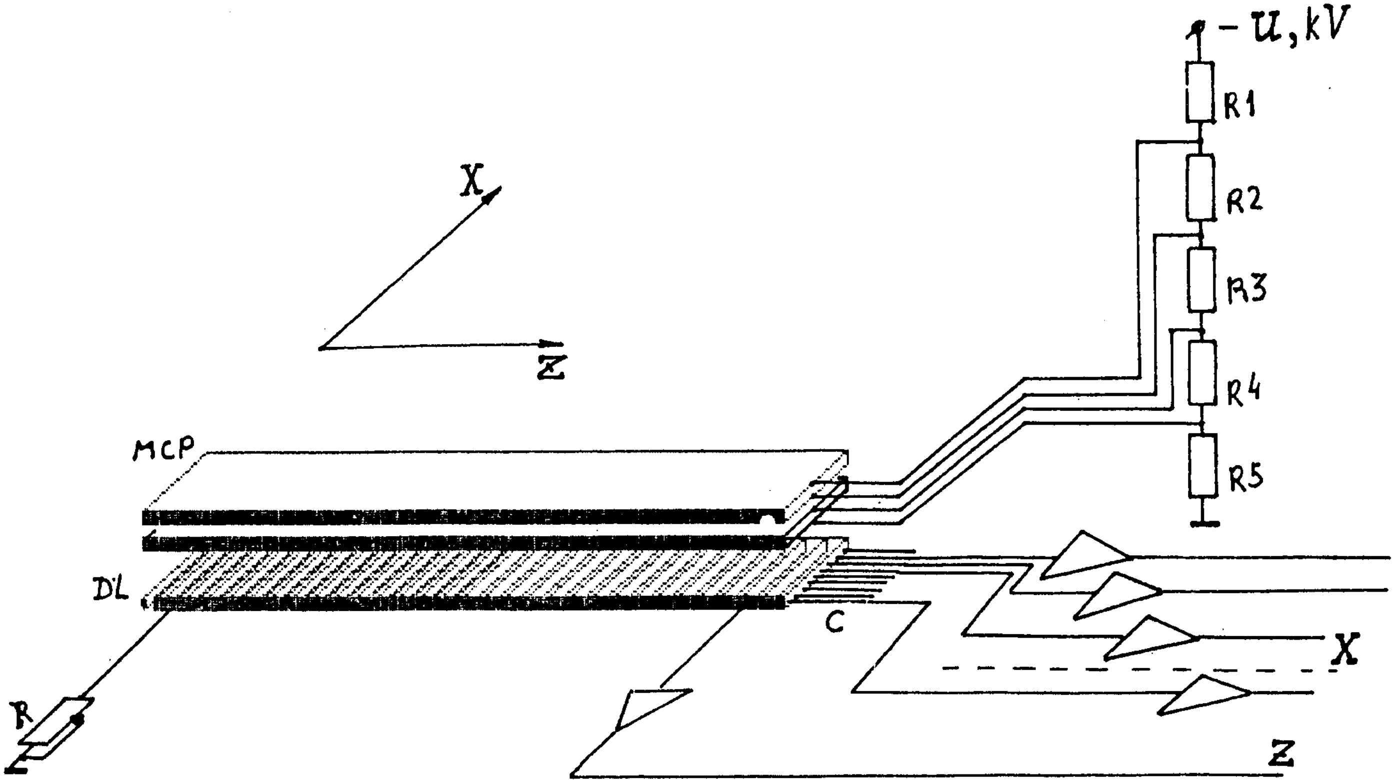

Fig.3. General idea of a new type coordinate MCP detector module. MCP — microchannel plates; DL — flat delay line; C — longitudinal strips situated inside the DL.

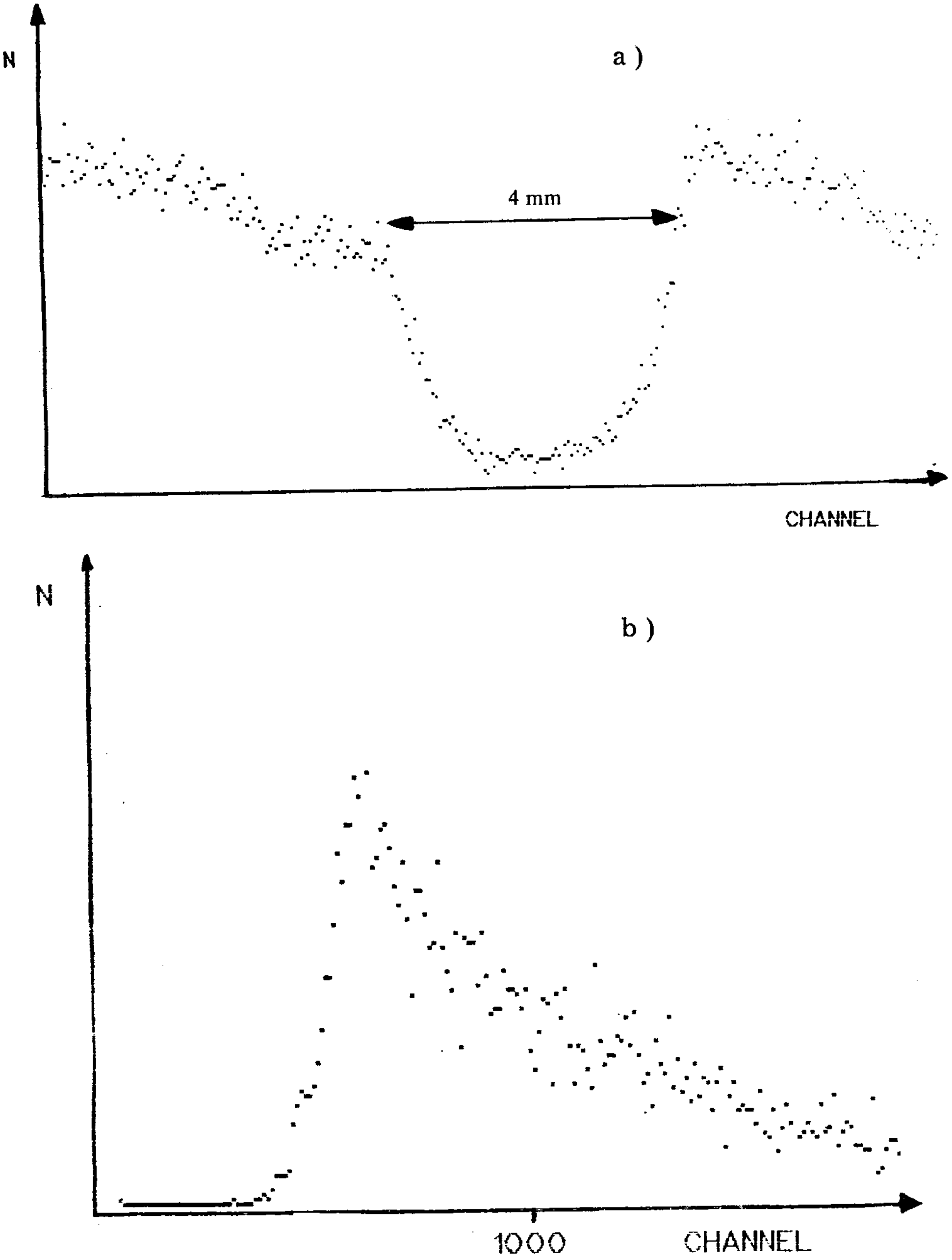

Fig.4. a) The part of the time spectrum giving the information about spatial (Z-axis) resolution ($\sigma = 500\,\mu m$). b) The edge of the time spectrum measured with better time resolution (time scale 0.05 ns/channel, spatial resolution $\sigma = 150\,\mu m$).

The measurements of a spatial resolution along Z-axis were done with the mask that shadowed the center of the plate. In oder to diminish the spatial uncertainty connected with mask and detector misalignment and with the finite α-source dimensions we have placed the thin (100 μm) mask directly on the MCP's surface. Besides we used the induced start signals from only one strip. Thus we evaluate this uncertainty to be less than 10 μm and the whole spatial accuracy is derived mainly by the time measurements resolution.

Figure 4 shows the results of spatial resolution measurements done with two values of time resolution obtained in a different runs. We did not make any exhaustive efforts with the standard equipment used in this test (f.e., self-rise time for the charge sensitive preamplifiers was 20 ns). Thus the obtained results (σ_Z = 150 μm and 500 μm — fig.4a,b) are the illustration of the idea. The inhomogeneity of the time spectrum in the vicinity of the mask and the background below the mask (see fig.4) may be connected with some additional surface electron noise produced by the mask and by electrons from the mask edge knocked by α-particles.

5. Conclusions

The first measurements of the efficiency of the registration of high energy charged pions and protons by a tandem of microchannel plates gave the result of (80±10)% that allows us to make the proposals for a new type of a vertex detector that includes MCP advantages as a detector and is capable of precise time and two space coordinates determination.

The authors are thankful to V.V.Krasnov, O.OPatarakin and L.B.Golovanov for their support of the work, to M.V.Aprelev for the preamplifiers and to all the JINR colleagues who helped us in this work.

References

1. Ainbund M.R., Polenov B.V. — "Secondary-Electron Multipliers of Open Type and Their Application", Moscow, Energoizdat, 1981.
2. Valiev F.F., Sergeev V.O. — Nuclear Spectroscopy and Nucl. Structure, Thes. Reports on 34th Conference, 1984, p.516.
3. Bogdanov D.D. et al. — JINR Preprint P13-90-356, Dubna, 1990.
4. Rodin A.M. et al. — JINR Preprint P13-88-581, Dubna, 1988.

5. Keller H. et al. — NIM, 1987, A258, No.2, p.221.
6. Andreev A.N. et al. — Nuclear Spectroscopy and Nucl. Structure, Thes. Reports on 41st Conference, 1991, p.421.
7. Particle Properties Data Booklet, CERN, 1990.
8. Morenzoni E. et al. — NIM, 1988, A263, No.2—3, p.397;
   Smith H.D. et al. — IEEE Nucl. Sci., 1986, 33, p.2985.
9. Krasnov V.A. et al. — Preprint FUB-HEP/90-27, Freie Univ. Berlin, 1990.
10. Barabash L.S. et al. — JINR Preprint P13-89-445, Dubna, 1989.
11. Skubic P. et al. — Preprint SLAC-PUB-5384, 1990.

Received on September 10, 1991.