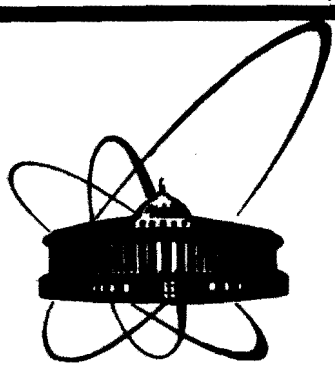

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E13-86-501

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TIME-ZERO DETECTOR BASED ON MICROCHANNEL PLATES AND A FRIABLE DIELECTRIC EMITTER

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1986

1. INTRODUCTION

In the recent years the time-of-flight technique was widely used to determine the mass of heavy-ion reaction products. One of the reasons for that is the possibility of using the transmission detectors based on microchannel plates (MCP) for measuring the time-of-flight of passing particles [1-4]. The main advantages of such detectors are a high time resolution (intrinsic time resolution of about 70-100 ps), reliability and simple design.

A MCP is used in time-zero detectors as a fast multiplier of secondary electrons emitted by charged particles passing through a foil and then isochronously collected with a magnetic [1] or electrostatic [2] systems on the MCP's mounted in a chevron configuration.

The typical multiplication factor for a configuration with two MCP is 10^6-10^7.

For the measurements of fission fragments or fission-like products (with an energy of ~ 2 MeV/n) emitters from thin (10-30 $\mu g/cm^2$) organic or carbon foils give an efficiency of about 100%. For high-energy reaction products, however, these emitters are inadequate because of the very low (≤ 1) secondary electron emission coefficient [6]. For example, for ^{4}He with an energy of 7.5 MeV/n the efficiency of detection was only a few per cent for a trinitrocellulose emitter [6].

One of the most effective and simplest ways to increase the detection efficiency is, in our view, to use emitters with control of secondary electron emission (CSEE) by means of friable dielectrics [7,8].

The CSEE is the process of electron emission from the layer of a friable dielectric in the strong electric field produced between two electrodes placed on both sides of the layer.

The friable dielectric layers are produced by evaporation in a vacuum of CsI, KCl or LiF salts onto a support which is used, at the same time, as one of the electrodes. The evaporation is provided in an inert gas at a pressure of several torrs, whereas layers of magnesium oxide (MgO) are obtained by deflagration of polycrystalline magnesium in thin air and by depositing its oxide onto a support. Depending on the evaporation conditions (the deflagration temperature, the distance between magnesium and collecting supports, air pressure, deposition time, etc.) it is

possible to obtain layers with a thickness from 30 $\mu g/cm^2$ to several mg/cm^2 with a relative density ρ/ρ° ranging from 0.3 to several per cent (ρ° being the density of a MgO monocrystal). As a result of that evaporation process, a friable dielectric emitter with the channel structure presented in fig. 1, is produced. The investigations of CSEE show that for friable dielectrics the coefficient of secondary electron emission in an electric field of $E \geq 3 \times 10^4$ V/cm is more than 10 times greater than that for normal solids [7]. This fact can be explained as follows: the emission of electrons occurs from the entire volume of a friable dielectric and then their number is multiplied in the intrinsic channels in the strong electric field. In such an interpretation the CSEE process is very similar to the electron multiplication in a MCP [9].

II. DESCRIPTION OF THE TIME-ZERO DETECTOR

The principle of operation and design features of our detector are analogous to those presented in ref. [2]. Fig. 2 shows a schematic view of the detector. The detector consists of five parts: a CSEE emitter with a MgO layer, an acceleration harp, an electrostatic mirror, two MCP's in a chevron configuration

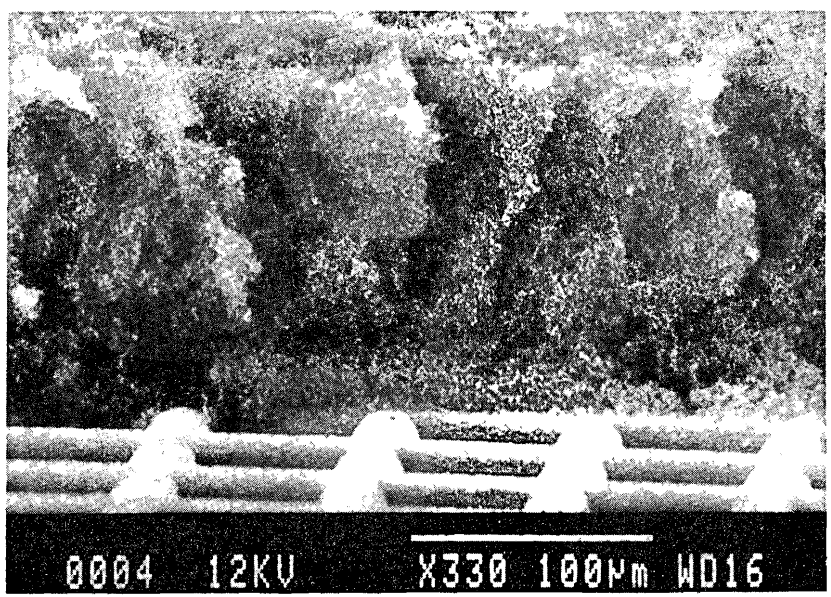


Fig.1. Electron microscope photograph of the friable dielectric layer (MgO) evaporated onto a grid-support.

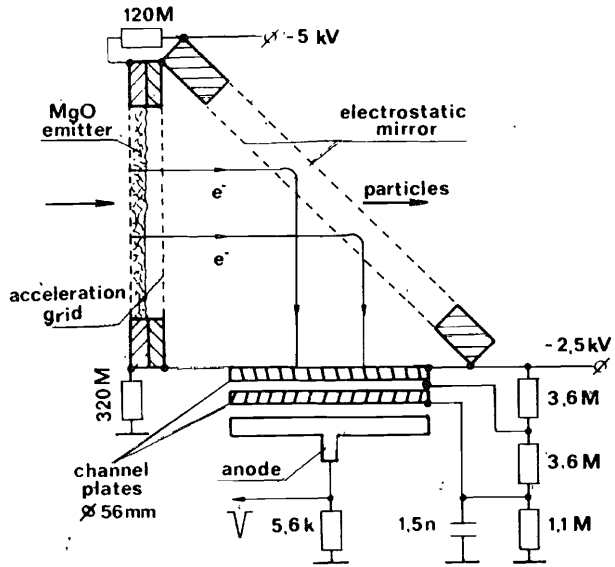


Fig.2. Schematic view of the time-zero detector.

and a flat anode. A MgO dielectric has been chosen because of its high nonhydroscopic properties (in contrast to other dielectrics such as CsI, KCl and LiF) and, at the same time, of its very good electron characteristics. A layer of MgO was evaporated onto a nickel grid with a thin (~ 10 $\mu g/cm^2$) trinitrocellulose foil as a backing. In order to obtain a high multiplication coefficient at an acceleration of emitted electrons to an energy of about 1 KeV, an electric field of $E \geq 10^4$ V/cm is applied between the grid-support of MgO and the accelerating harp. After bending in the electrostatic mirror through 90° the electrons were collected on the MCP's where their number is multiplied by 10^6-10^7 times. Output pulses are obtained from a flat anode placed under the MCP's. The main characteristics of our detector are presented in the table.

III. EXPERIMENTAL TESTS WITH A HEAVY-ION BEAM

1. Experimental Set-Up

A test of the detector has been performed with a heavy-ion beam from the GANIL accelerator. $^{16}O^{8+}$ ions with an energy of 50 MeV/n bombarded a gold target (thickness ~ 100 mg/cm^2). The reaction products were selected by the LISE magnetic spectrometer [10]. The time-zero detector was mounted after the second

Table

I - Secondary electron emitter
grid-support: Ni wires, 92% transparency, layer of trinitrocellulose with thickness, ~ 10 $\mu g/cm^2$
friable dielectric: MgO with relative density, $\rho/\rho_o \leq 1\%$ (ρ_o = 3.65 g/cm^3), thickness, ~ 100 $\mu g/cm$. accelerating harp: Be-bronze wires with $\phi 90$ μm, step between wires, 1 mm.
electric field, $E \geq 10^4$ V/cm

II - Electrostatic mirror
two parallel harps (same as accelerating harp), distance between them: 7.5 mm

III - Electron multiplier
2 MCP in a chevron configuration, $\phi 56$ mm each, distances MCP-MCP and MCP-anode 1 mm each,
anode: $\phi 60$ mm flat,
multiplication factor 10^6-10^7 at high voltage, 2.2-2.5 kV.

dipole magnet of the spectrometer (Fig. 3). At about 6 m downstream a 1 mm thick ΔE semiconductor detector was placed at the achromatic refocusing point of the spectrometer. In order to sustain a not too high counting rate for the ΔE detector the spectrometer was set to a magnetic rigidity corresponding to the transmission of (helium-like) $^{16}O^{6+}$. The spectrometer was limited to a momentum acceptance of $\Delta p/p$ = 0.2%. The output pulse from the time-zero detector was directly fed to a 7174 Enertec constant fraction discriminator (CFD). The time signal derived from the ΔE detector by means of a fast preamplifier and another constant fraction discriminator served as a START input for a 566 ORTEC time-to-amplitude converter (TAC) which was stopped by the delayed timing signal of the time-zero detector.

The start and stop input had been reversed in order not to untimely trigger the TAC on background pulses from the MCPS. The output pulses from the TAC were analysed by a SILENA (Cato) multichannel analyser.

2. Results

The efficiency of the detector depends of course strongly on the discrimination threshold. For the actual oxygen beam, representing the "worst case" of a light ion of high energy (i.e., small energy loss), an efficiency of 70% was found for a discriminator threshold of 70 mV, decreasing to 50% for a setting of 150 mV.

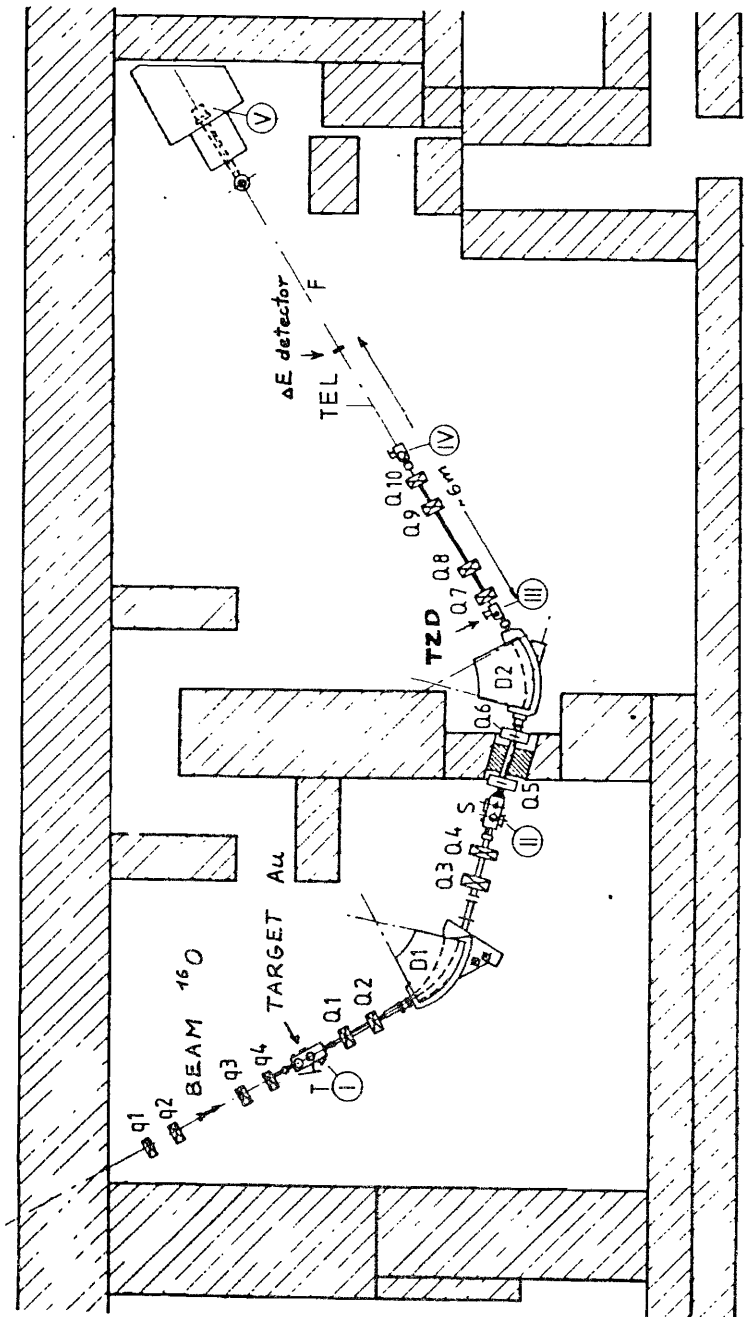
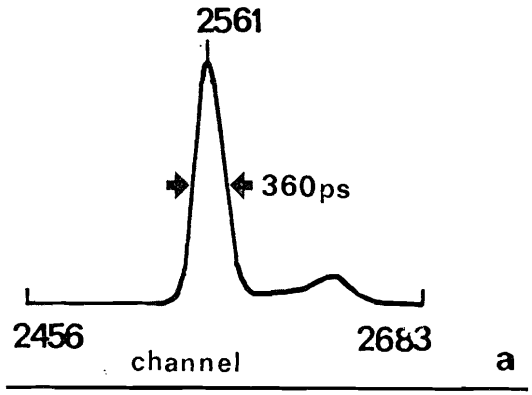


Fig. 3. Experimental set-up.



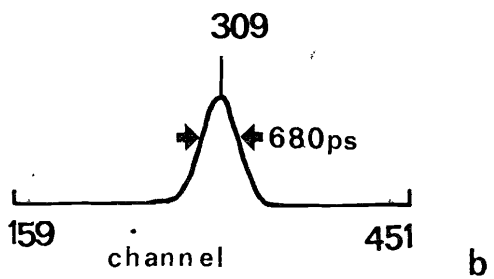


Fig. 4. Time-of-flight spectra for $^{16}O^{6+}$ ions measured in the system: a) time-zero detector-semiconductor ΔE detector; b) time-zero detector - CSS2 accelerator radio frequency.

The result of the time resolution measurement is shown in Fig.4a), where a FWHM of 360 ps is obtained. This value is consistent with a convolution of several contributions which have to be taken into account:

i) the time-of-flight of the oxygen particles over the 6 m distance amounts to 65 ns which, since $\Delta p/p = 0.2\%$ lead to a width of ~130 ps of the beam itself.

ii) the intrinsic width of the time-zero detector (~100 ps),

iii) the "walk" of the constant fraction discriminator. This contribution is relatively large since the input pulses cover a wide span. From the operating manual of the CFD a value of 270 ps is found for an input between several volts and the threshold setting,

iv) the width induced by the ΔE detector timing chain (~ 150 ps).

Fig. 4b) shows, for comparison, the resolution which is obtained by stopping the TAC by the radio-frequency pulse of GANIL accelerator in lieu of the signal from the time-zero detector. A FWHM of 680 ps is observed. This value is still relatively good and associated with the very satisfactory operation of the new ECR ion source for gaseous materials. For metallic ions however, produced by the PIG source, values of up to 2 ns have been found, accompanied by occasional phase shifts of several ns. Here the use of a time-zero detector of the proposed type will give a substantial improvement.

The test of the detector will be pursued with heavier beams in order to obtain a complete picture of its potential and performance.

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Received by Publishing Department
on July 18, 1986.

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Лукьянов С.М. и др.
E13-86-501

Временной детектор на основе микроканальных пластин и рыхлого диэлектрического эмиттера

Описан временной детектор на основе эмиттера из рыхлого диэлектрика с использованием изохронной транспортировки вторичных электронов на шевронную сборку микроканальных пластин. Детектор предназначен для получения временной отметки для времяпролетной методики определения массы продуктов реакций с тяжелыми ионами. Приводятся результаты испытания временного разрешения детектора на пучке ионов ^{16}O с энергией 50 МэВ/нуклон ускорительного комплекса ГАНИЛ /Франция/.

Работа выполнена в Лаборатории ядерных реакций ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1986

Lukyanov S.M. et al.
E13-86-501

Time-Zero Detector Based on Microchannel Plates and a Friable Dielectric Emitter

A time-zero detector using a friable dielectric emitter and isochronous transport of secondary electrons onto a chevron device is described. The detector is intended to obtain time mark for time-of-flight method which is used to determine the mass of heavy-ion reaction products. Test results of time resolution for detection on ^{16}O beam with 50 MeV/nucleon energy from the GANIL accelerating complex (France) is given.

The investigation has been performed at the Laboratory of Nuclear Reactions, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna 1986