PROPORTIONAL CHAMBER OPERATION AT LOW TEMPERATURES

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1. Introduction

In order to study the e^+e^- annihilation at the storage ring facility VEPP-2M [1], a cryogenic magnetic detector (CMD) [2]has been made. A schematic view of the detector is shown in Fig.1. The six-gaps optical spark chamber (6) is mounted inside a superconducting solenoid (7). The solenoid and the spark chamber axes are parallel to the direction of particle motion in the storage ring. The distinctive feature of the detector is its operation at low temperature to get a higher density of a gas mixture in the spark chamber. The chamber operation at a temperature of 180 K and pressure of 2 atm allows a spatial resolution of about 50 μm. For triggering of the spark chamber two cylindrical multiwire proportional chambers (8,9) (MWPCs) operating with the same gas mixture are used. The absence of additional walls between the spark chamber and MWPCs decreases a multiple scattering of charged particles in the detector.

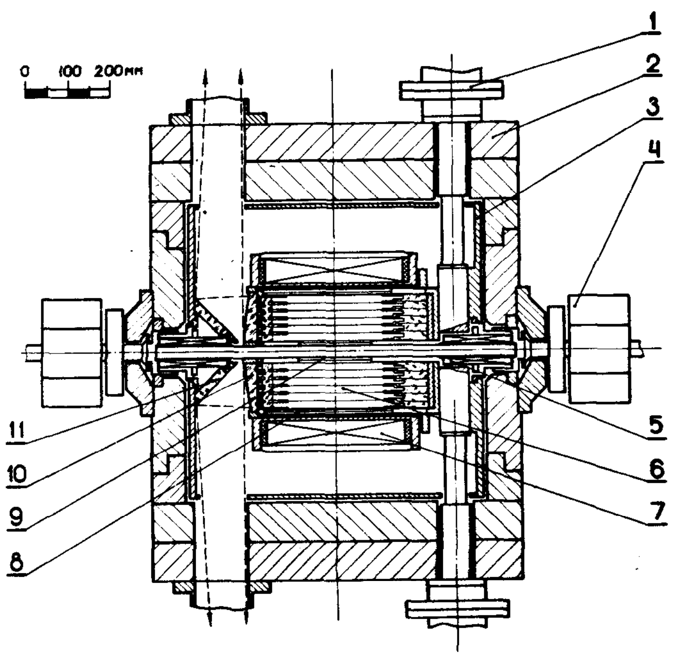

Fig.1. The schematic cross section of the detector: 1 - high voltage feeding, 2 - yoke, 3 - nitrogen shell, 4 - magnetic lens of the storage ring, 5 - compensating solenoid, 6 - spark chamber, 7 - main solenoid, 8 - outer MWPC, 9 - inner MWPC, 10 - optic lens, 11 - mirror.

The momentum resolution $\sigma_p/p = 0.05 \cdot p$ (GeV/c) has been obtained at 32 kG magnetic field in the centre of the detector. The solid angle covered by the CMD is $0.6 \times 4\pi$. Two compensating superconducting solenoids (5) are employed to cancel the influence of the main solenoid field on the circulating beams. Only charged particles are detected by the CMD.

2. Experiments with MWPCs at low temperatures

The operation of MWPC at low temperatures was studied to find a suitable gas mixture at the lowest temperature. Some results of these experiments were given in Refs.3,4 . The gases CH_4 and CO_2 were used as quenching admixtures to noble gases for normal operation of MWPC at low temperature. The CH_4 admixture allows to operate at a temperature of 78 K (liquid nitrogen temperature) and for CO_2 this temperature is about 160 K. At these temperatures the vapour pressures of CH_4 and CO_2 are 0.015 atm and 0.03 atm, respectively. In our detector the volume percentage of these gases cannot be more than 3-5% because of the deterioration of the efficiency and the spatial resolution of the spark chamber.

In these experiments the MWPC with 3 mm gap between 28 μm gold plated tungstem wire and cathode electrodes was used. This gap was chosen to minimize a volume of the MWPC triggering system in the magnetic field of the detector. The wire spacing was 2 mm, the wire length was 15 cm. The Ne + 0.7%CH_4 + 2.5%Ar gas mixture at 78 K and a pressure of 2 atm was used as MWPC filling. The operating high voltage (HV) under this condition was 1500 V. The MWPC counting rate was 10^3 Hz per wire caused by the radioactive source.

The following phenomena were observed under these conditions:

a) The MWPC with cathode electrodes made of metals with oxide films on their surfaces did not work. The copper, aluminium, titanium, stannum, stainless steel were tested. A few tens of seconds after switching on a HV current of 100 μA appeared through the chamber, the voltage drop on the limiting resistor increased that caused decreasing of the HV on the chamber and the MWPC lost its sensitivity.

To reduce the electric field in the vicinity of the cathodes, the wire spacing was changed from 2 mm to 4 mm, that led to decreasing the electric field from ~3000 V/cm to ~1500 V/cm. This gave the opportunity for MWPC with aluminium cathodes to operate during about 30 hours. Then the sensitivity was lost due to HV decreasing.

This kind of behaviour of MWPC could be explained by an increase in the resistivity of the oxide film on the cathode surfaces at low temperature. The ions built up the surface charge on this film, put out the electrons from the cathodes and the current appeared. The building time of the ion surface charge required for the appearance of a current through the chamber strongly depends on the electric field in the vicinity of the cathodes.

b) The MWPC with the gold plated cathode and a 2 mm wire spacing operated about 8 hours. Then the current appeared and the sensitivity was lost due to HV decreasing. The temperature increase by 10-15 degrees led to disappearing the current through the chamber for a few hours. These steps continued up to the temperature at which CH_4 could be replaced by CO_2. The non-regular dark film was found on the surface of the cathodes which could be partly washed out by alcohol.

At room temperature the MWPC operation with this mixture is stable for a long time. This behaviour could be explained by the CH_4 radicals polymerisation which increased at low temperatures. The similar effects of current appearance in the MWPC at room temperature was described in Refs. 5,6,7,8,9.

The noble gases with admixture of CO_2 are suitable for MWPC operation at temperatures higher than 160 K.

3. The MWPC construction and gas mixture used in the CMD

The construction of the MWPCs and the spark chamber used in the CMD is shown in Fig.2. The inner and outer MWPCs have been wound with the 28 μm gold plated tungsten wires (10) with 4 mm wire spacing, 3 + 3 mm gaps width for outer and 3 + 4 mm gaps for inner ones because of the small radius of the inner MWPC. The inner MWPC has been mounted on the vacuum pipe of the storage ring. The wires are soldered to the copper strips put on the plexiglass isolating rings (11). The sizes of the plexiglass rings and aluminium cathodes (8) which had different heat expansion coefficients were selected to have the constant wires tension with cooling.

The stainless steel pipe (7) with a 0.05 mm wall thickness was used as a storage ring vacuum pipe near the beam interaction point.

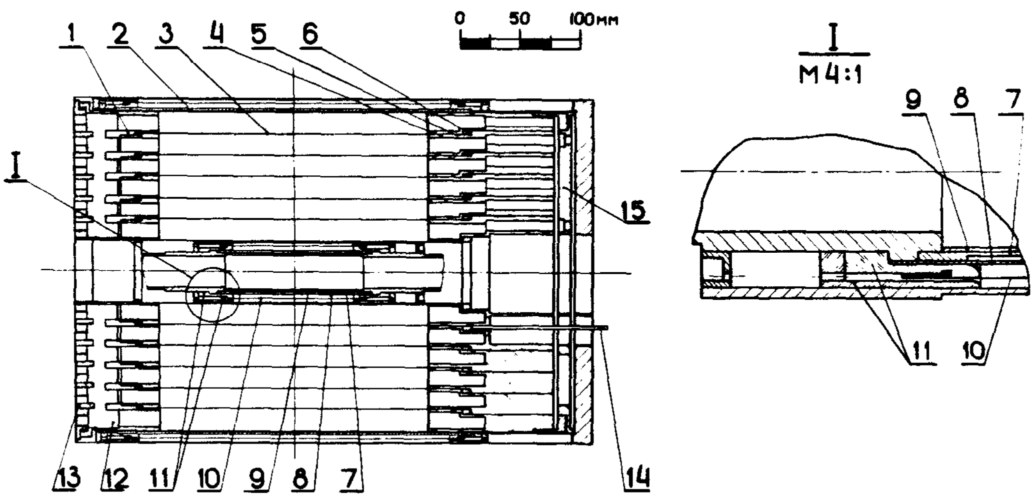

Fig.2. The elements of the spark chamber and MWPCs: 1,4,5 - isolating rings, 2 - outer electrode of the spark chamber, 3 - foil electrode, 6 - aluminium ring, 7 - vacuum pipe, 8 - MWPC electrode, 9 - berillium pipe, 10 - sense wire, 11 - isolating ring, 12 - front wall, 13 - prisms, 14 - HV electrode, 15 - back wall.

A berillium pipe (9) with a wall of 1 mm thick put inside the vacuum pipe to prevent it from the outer pressure destruction. The cathodes of the inner MWPC have been made of 0.15 mm gold plated aluminium. The total thickness of the vacuum pipe and the electrodes of the MWPC is equal to 0.3 g/cm^2 or 0.009 radiation length.

The mixture of Ne + 8%Ar + 2.5%CO_2 was found to be suitable at low temperature for the spark chamber and MWPCs. The chambers operate at a temperature of 180 K and a pressure of 2 atm. The gas flow rate is about 5 cm^3 per minute. Under this condition the operating HV of the MWPCs is about 1500 V and MWPCs have the plateau width of about 100 V with nearly 100% efficiency. The MWPCs time resolution is $2\tau = 100$ ns.

4. The operation of the MWPCs as a CMD triggering system

The wires in each MWPC were ordered in 16 groups. The high voltage was applied to the sense wires. The signals from every group were taken through a dividing capacitors and proceeded via 50 Ω cables to the amplifiers, which were placed outside of the detector at a 5 m distance. The input threshold was adjustable and was normally set at 3 μA. The selection of the desirable coincidence was carried out by the block of the trigger logic, which could be changed. The triggering rate of the detector was less than 1 Hz at maximum luminosity of the storage ring. The inner MWPC operated at about 10^4 Hz per wire and the outer one operated at ~ 10^2 Hz per wire. Every $2 \div 3 \cdot 10^4$ discharges in the spark chamber caused the 20 V increase in the operating HV on the MWPCs due to the gas mixture changing. The gas mixture used to be replaced after about 10^5 triggers of the spark chamber. The MWPCs operate with CMD about four years. There were no broken wires and no changes in MWPCs' parameters were noticed.

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