BACKGROUND CONDITIONS IN THE DETECTOR MD-1 WITH PERPENDICULAR MAGNETIC FIELD

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Summary

The magnetic field in the MD-1 is perpendicular to the orbit plane of a storage ring. This allows the analysis of the particles going out even at zero angles, that is especially important for the two-photon processes. The background problems caused both by the showers of the particles lost in the storage ring and by synchrotron radiation are considered in the paper presented here. With the trigger conditions sufficiently weak at an energy of 1.8 GeV the background due to showers does not exceed 1 Hz/mA. The background caused by synchrotron radiation in the Υ - meson region is not essential for the beam current up to 10 mA.

I. Introduction

The distinctive feature of the detector MD-1 is that its magnetic field is perpendicular to the orbit plane[1]. Such a version has the following advantages compared to the detectors with the longitudinal field.

1. There is a possibility to detect particles and to analyze their momenta for the whole range of angles θ, including $\theta = 0$. It is essential especially for the two-photon processes with an angular distribution of the scattered electrons and produced particles peaked forward.

2. It is convenient to detect the γ - quanta going out at zero angles - the low background level and large aperture. This opportunity has been already used in the experiment on the study of the Bremsstrahlung process where the interesting effect of the cut-off of large impact parameters has been observed[2].

The main disadvantage of the detector with the perpendicular field is the more complicated background problems because of the particle loss in the storage ring and synchrotron radiation. The study of the background caused by lost particles has been carried out at the VEPP-4 injection energy of 1.8 GeV. The measurement of the background due to synchrotron radiation has been performed in the Υ -meson region.

II. The detector MD-1.

The layout of MD-1 at VEPP-4 is shown in Figs. 1,2. The interaction region is inside the large magnet. From both sides of the magnet two additional magnets have been placed with separate supplies. This allows variation of the detector field keeping the angle of the orbit bending constant and equal to 16°.

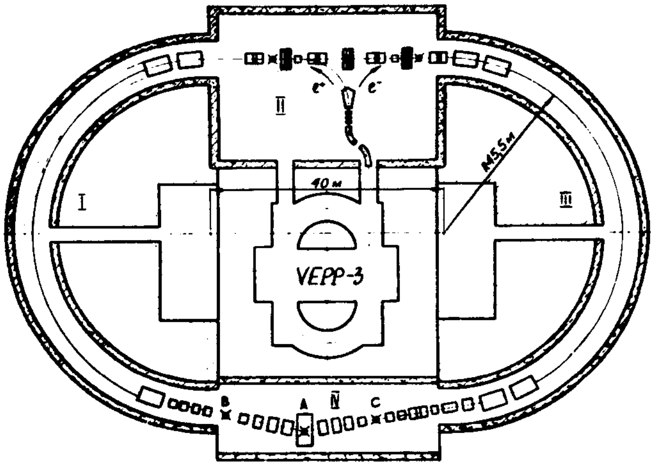

Fig. 1. The layout of VEPP-4:
A - interaction region for the detector MD-1; B,C - interaction regions.

The electron tagging system for studying the two-photon processes is installed

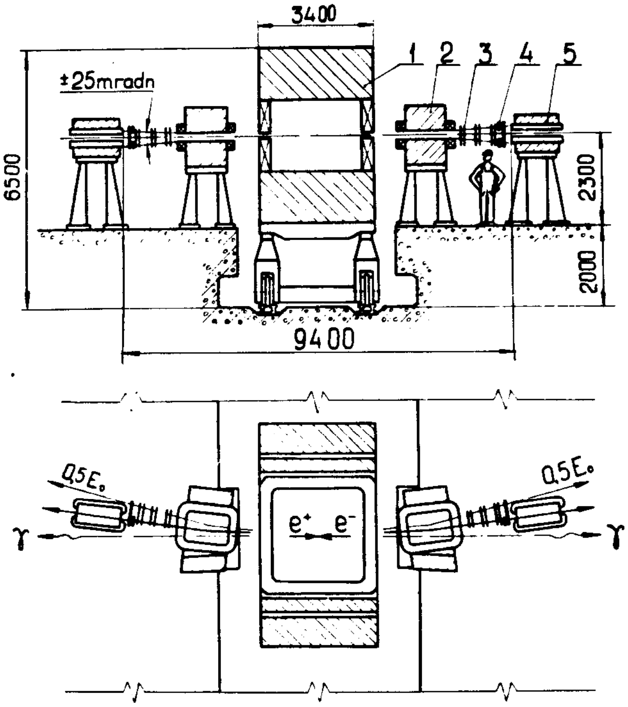

Fig. 2. The central interaction region: 1 - detector MD-1; 2 - additional bending magnets; 3,4 - electron tagging and luminosity monitoring system; 5 - lenses.

between additional bending magnets and lenses. The system consists of induction proportional chambers, measuring the radial coordinate with an accuracy $\sigma = 100\ \mu m$, usual proportional chambers and scintillation counters. The accuracy of measuring the energy of scattered electrons is 1%. The system is placed from the inner side of the orbit and also above and below the beam. The system ensures detection of the electrons scattered at $\theta = 0°$, with the energy loss of 15-50%. The electrons with the beam energy are detected at the angles θ = 12+100 mrad.

The central part of the detector is shown in Fig. 3. The magnet is a closed-type solenoid. The internal size of the coil is 2.3x2.3 m^2, the copper coil thickness is 30 cm, the gap is 1.8 m, the maximum field is 16 kG. Starting from the interaction region the detector contains a vacuum chamber, coordinate chambers, scintillation counters, gas Cerenkov counters and shower-range chambers. Besides that the muon chambers are placed beyond the magnet winding, inside and beyond the yoke.

A trigger is arranged by the hierarchy principle: primary trigger, secondary trigger, computer[3].

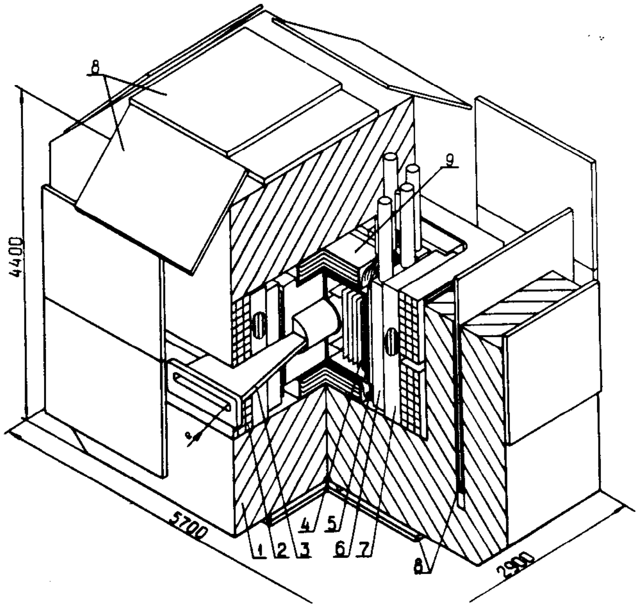

Fig. 3. Magnetic detector MD-1: 1 - yoke, 2 - copper winding, 3 - vacuum chamber, 4 - coordinate chambers, 5 - scintillation counters, 6 - gas Cerenkov counters, 7,9 - shower-range chambers, 8 - muon chambers.

III. Background due to the loss of the particles in beams

The background counting rates from the particles lost from the beam have been studied at the injection energy of 1.8 GeV. Measurements were carried out at the current of 0.3+1 mA. The large currents are restricted by the collision effects. At these currents the beam lifetime was 10+3 hours and determined mainly by the Bremsstrahlung radiation on the residual gas as well as by the Touschek effect.

Our measurements have shown the following nature of the background in the detector.

At first, there are particles leaving the equilibrium orbit and performing many turns before their ruin. The spacial density distribution of these particles (halo) is fairly broad and has sharp bounds . The cut-off of the halo occurs in the point where the storage ring aperture is the smallest. If this point is near the detector, it causes an increase in the background counting rate.

Secondly, the beam electrons lose their energy by the Bremsstrahlung radiation on the residual gas in the straight section in front of the detector and hit the detector after bending by the magnetic field.

In Fig. 4 the result of the halo size measurement is shown. The probe, placed beyond the first lens from the detector is moving in the vertical direction. The dependence of the primary trigger counting rate on the probe position was measured. The solid line shows the result when the probe approaches the beam from below and above. It is seen that the halo size is about 4 cm. The dotted line shows the result of the similar measurement at an aperture restriction in the injection section. The decrease in the halo size can be seen.

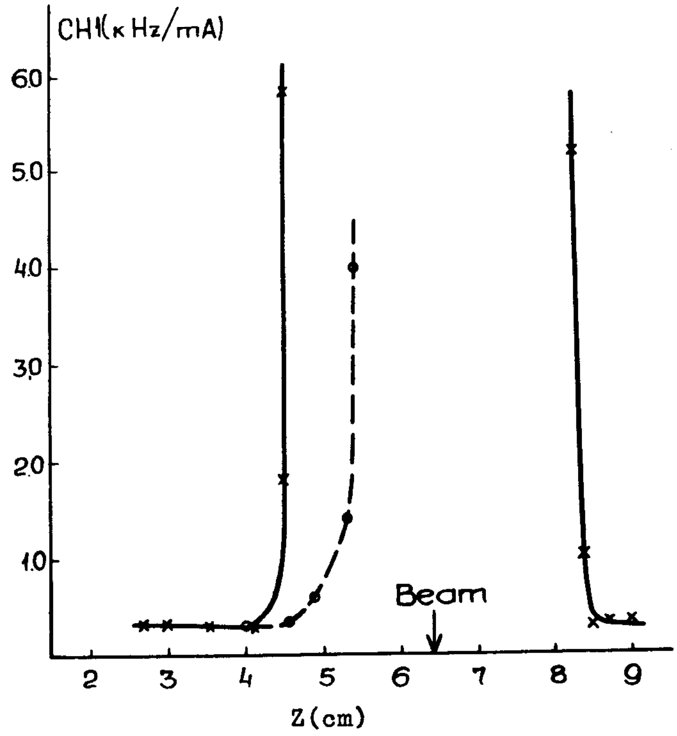

Fig. 4. The dependence of the primary trigger counting rate on the position of the probe; solid line - no cut-off of the storage ring aperture, dotted line - with the restriction of the aperture in the injection section.

In Fig. 5 the dependence of the background counting rate of the detector on the vertical position of the beam in the detector is presented. Curve 1 - without restriction of the aperture, curve 2 - with the restriction of the aperture in the injection section. It is seen that the background has been decreased and the dependence on the beam position has disappeared. The cut-off of the halo in the injection section was performed in vertical, radial and in both directions simultaneously. The background counting rate is practically the same in all these cases. This shows that particles in the halo live many turns.

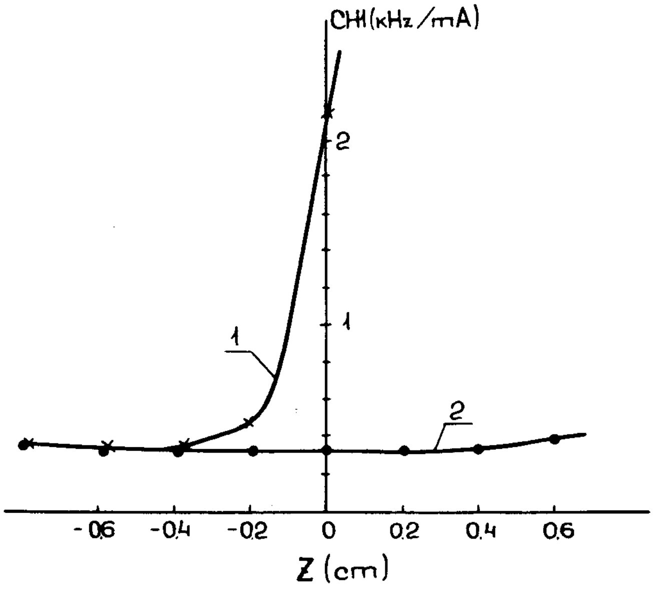

Fig. 5. The dependence of the primary trigger counting rate (CH1) on the vertical beam displacement in the MD-1: 1 - no restriction of the aperture, 2 - with the restriction of the aperture in the injection section.

In Fig. 6 the dependence of the background counting rate on the radial displacement in the detector is shown. Such a large orbit displacement is possible due to large sizes of the vacuum chamber in the detector and is carried out by the variation of the field in the central and additional bending magnets.

For experiments at the energies close to the injection one we have chosen the radial displacement Y = 9 cm and have used the halo cut-off in the injection section.

Different chambers and counters have highly different background counting rates.

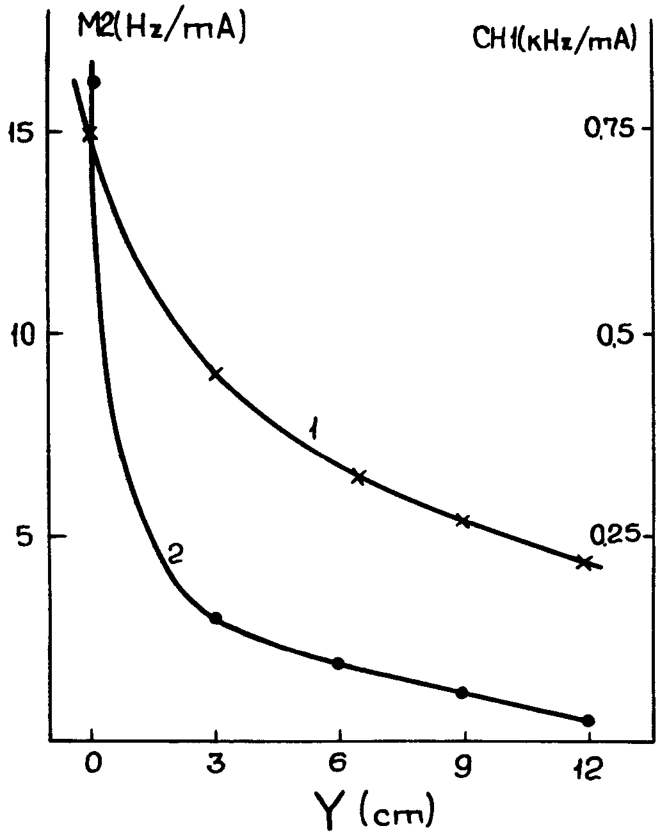

Fig. 6. The dependence of the background counting rate of the detector on the radial displacement of the beam in the MD-1. The restriction of the aperture is made. 1 - counting rate of the primary trigger (CH1), 2 - counting rate of the secondary trigger (M2).

In the Table 1 the data for the chambers and counters with the maximum counting rate are presented.

Table I. The background for the chambers and counters with the maximum counting rate at E = 1.8 GeV.

System	Background counting rate, kHz/mA
1. Coordinate chamber	0.3
2. Scintillation counter	0.3
3. Shower-range chamber	1
4. Tagging system	1

To decrease the trigger counting rate from the background due to the Bremsstrahlung radiation of electrons on the straight section in front of the detector we have used scintillation sandwiches detecting the Bremsstrahlung γ - quanta. The vacuum chamber has thin windows in these directions. The angular distribution of these photons is fairly sharp, therefore the sizes of the sandwiches are small (10x10 cm^2). The counting rates of these counters are about 3 kHz/mA. These counters are included in the trigger on anticoincidence that leads to the reduction of the trigger counting rate by a factor of 2÷3.

Upon these conditions the counting rate of the primary trigger via the channel of charged particles CH1 (at least one particle is needed in the unit of three coordinate chambers and firing of at least one scintillation counter) is about 0.2 kHz/mA, and via the neutral channell N1 (firing of two of ten chambers in the shower-range module is required) is about 0.5 kHz/mA.

The use of various combinations of the secondary trigger allows to reduce strongly the number of the tape recorded events. Below we present the data on the counting rates for some combinations of the secondary trigger in terms of our notations jargon.

1. M1 = CCND = 10 Hz/mA

Two units of the coordinate chambers and at least one scintillation counter were fired.

2. M2 = CCND*CCU*CCL* SCUL = 1 Hz/mA

Two units of the coordinate chamber were fired, one of them is near upper (near lower), another one is a distant lower (distant upper) and there are scintillation counters below and above. The data on the counting rates for these trigger conditions are presented in Fig. 6.

3. M3 = M2*SHND = 0.15 Hz/mA

Besides the condition 2 firing of two shower-range units is required.

IV. Background due to synchrotron radiation

The special paper[4] is devoted to the solution of the background problem caused by synchrotron radiation (SR) in the MD-1 detector. The basic idea of the solution consists in creation of the special vacuum chamber allowing to synchrotron radiation to pass the detector without touching the vacuum chamber walls (Fig. 7). Radiation receivers are placed at a rather long distance from the detector center, so that only backward scattered photons hit the detector. This allows to reduce considerably the photon flux on the central part of the vacuum chamber, especially in the hard part of the spectrum because at the Compton backward scattering the photon energy decreases and the angular distribution for hard photons is peaked forward. The movable collimator allows to choose an optimal size of the vertical aperture. The radiation receivers made of copper, are water cooled.

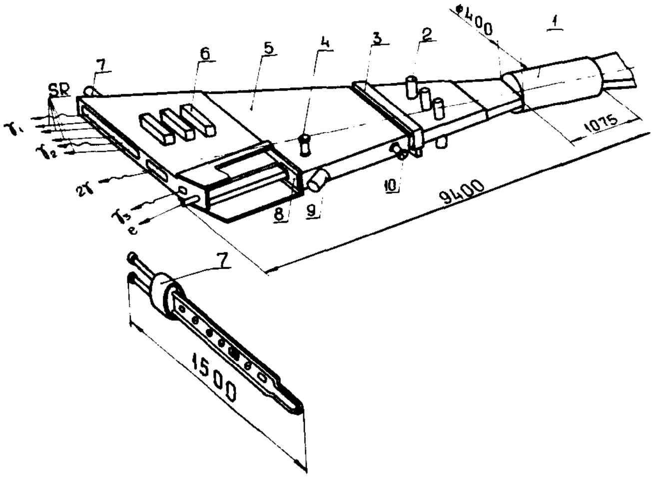

Fig. 7. The layout of the vacuum chamber in the central interaction region: 1 - cylindrical part, 2 - movable collimator, 3 - latch, 4 - vertical probe, 5 - chamber for SR escape, 6 - vacuum pumps, 7 - SR receivers, 8 - entrance window of the electron tagging system, 9 - electron escape for γ - quanta monochromatization, 10 - radial probe.

Such a construction of the vacuum chamber has reduced the photon flux at the central part of the detector by a factor of 10^6. An additional attenuation is achieved by placing a thin foil at the thin cylindrical part of the vacuum chamber and in front of the scattered electron tagging system. Now the cylindrical part is of 3 mm thick Al($1/30\ X_0$) and 0.1 mm Ta($1/20\ X_0$) and the tagging system window is of 0.17 mm thick Fe($1/100\ X_0$) and 0.3 mm Sn($1/40\ X_0$).

The background due to synchrotron radiation is essential only for the coordinate chambers and for the tagging system; the remaining elements of the detector are protected by a thick layer of material. For simplicity of the event analysis it is desirable to have the number of wires fired for the one beam passage less than one.

We have performed the measurement at the beam energy of 4.7 GeV. The number of fired wires during one beam passage at the current of 1 mA was 0.1 for the coordinate chamber nearest to the beam and 0.03 for the most distant one. For the chamber of the tagging system the corresponding value is 0.01. The experimental data are in agreement with calculations with an accuracy of about 2.

It is seen that at the present conditions the background due to synchrotron radiation allows to operate at the Υ - meson energy with the currents up to 10 mA.

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