И Н С Т И Т У Т
ЯДЕРНОЙ ФИЗИКИ СОАН СССР

ПРЕПРИНТ И Я Ф 77 - 75

MAGNETIC DETECTOR MD-1

S.E.Baru, A.A.Belavin, A.D.Bukin, V.R.Groshev, N.S.Dvornikov, G.M.Kolachev, Yu.V.Korshunov, G.D.Minakov, A.P.Onuchin, E.L.Panina, G.I.Proviz, I.Ya.Protopopov, G.A.Savinov, A.I.Shusharo, V.A.Sidorov, A.N.Skrinsky, V.I.Telnov, Yu.A.Tikhonov, A.I.Vorobiov

Новосибирск

1977

MAGNETIC DETECTOR MD-1

S.E.Baru, A.A.Belavin, A.D.Bukin, V.R.Groshev, N.S.Dvornikov,
G.M.Kolachev, Yu.V.Korshunov, G.D.Minakov, A.P.Onuchin, E.L.Panina,
G.I.Proviz, I.Ya.Protopopov, G.A.Savinov, A.I.Shusharo, V.A.Sidorov,
A.N.Skrinsky, V.I.Telnov, Yu.A.Tikhonov, A.I.Vorobiov

Institute of Nuclear Physics
Siberian Division of the USSR Academy of Sciences

Abstract

The magnetic detector MD-1 is intended for experiments at the electron-positron storage ring VEPP-4 with the energy up to 2 x 7 GeV. The detector magnetic field is perpendicular to the orbit plane. The detector consists of the following basic components: a magnet with field volume of 9.5 m^3, a system of coordinate proportional chambers, shower-range chambers, muon chambers, gas Čerenkov and scintillation counters. An electron tagging system is envisaged for investigation of electroproduction processes.

Contents

The detector MD-1 is a magnetic detector intended for experiments at the electron-positron storage ring VEPP-4 with the beam energy up to 2 x 7 GeV /1/. The distinctive feature of the detector is that its magnetic field is perpendicular to the orbit plane. Such a variant allows particle detection and momentum analysis for all angles θ between the particle direction and beam axis. For some processes with angular distribution of final particles peaked forward (for example, electroproduction processes) detection of particles at small angles is essential. Such a system allows detection of Bremsstrahlung photons flying along the orbit tangent. The detector magnet changes the direction of the beam motion, thus its magnetic field depends on the beam energy. Due to perpendicular magnetic field the interaction region must have special protection from synchrotron radiation.

1. Organization of the interaction region in VEPP-4

The electron-positron colliding beam machine VEPP-4 consists of two half-ring with the average radius 45.5 m connected by two straight sections (Fig.1). One of this sections is intended for technical purposes and the other one 55 m long for experiments. It contains three interaction regions and 15 quadrupole lenses which match the section and provide necessary beam parameters.

In the central interaction region the magnetic detector MD-1 is placed with a magnetic field perpendicular to the orbit plane bending the initial beam by 16°.Two elements of periodicity have been removed to provide beam collision in the magnetic field of MD-1. Besides the main magnet two additional magnets with large aperture have been placed with separate supplies allowing variation of the detector field at a fixed field integral.

For ensuring high luminosity the nearest to the interaction point lenses have large aperture. Their construction (lenses don't take place in the orbit plane) provides additional possibilities for experiments.

Basic parameters of the central interaction region are placed in Table 1.

Table 1.

Parameters of integration region

Distance between lenses (m)		9.5
β_z (cm)		46
β_r (cm)		223
Radial beam size	$2\sigma_r$ (cm)	$5.8\cdot10^{-2}$ E
Vertical size	$2\sigma_z$ (cm)	$1.8\cdot10^{-2}$ kE
Longitudinal size	$2\sigma_\ell$ (cm)	$80\sqrt{E^3 V^{-1}}$
Luminosity (10^{28} cm^{-2} sec^{-1})		2.4 I^+E
Required electron current I^-(mA)		1.6 kE^3

Where:

I^+ - positron current in mA
E - beam energy in GeV
V - RF cavity voltage in kV
k - coefficient oscillation coupling.

By decreasing β_z to 10-15 cm one can increase luminosity up to 10^{29} E (GeV) $cm^{-2}sec^{-1}$ per 1 mA of positron current. This is possible if a focusing system of the straight section is reorganized after beam storage.

2. Basic parameters of the detector

The chosen version of the detector satisfies the following principal requirements:
1) the direction of the magnetic field is perpendicular to beam trajectory allowing

analysis of particles going out even at zero angles;

2) a large solid angle in order to make systematic errors in identification of reaction mode and in determination of the total cross sections small;

3) detection and determination of an energy of scattered electrons going out in the direction of initial particles;

4) the uniform magnetic field to provide rather simple data processing;

5) identification of e, μ, π, K and γ -quanta;

6) detection of γ -quanta going out at zero angles;

7) flexible triggering system for two-prong and multi-prong events, including neutrals; events classification;

8) time-of-flight measurements for rejection of cosmic background;

9) luminosity monitoring system for operation in wide range of luminosities.

The layout of MD-1 at VEPP-4 is shown in Fig.2. The interaction region is in the large magnet. From both sides of the magnet large aperture bending magnets are placed. At the energy 7 GeV the magnet field strength is 13.2 kGauss in MD-1 and 12.4 kGauss in neighbouring magnets. The additional bending magnets permit to detect scattered electrons with a smaller energy loss and improve considerably the energy resolution.

The electron tagging system for studying double electroproduction processes is installed between additional bending magnets and lenses. The system consists of inductional proportional chambers and scintillation counters at the inner side of the orbit as well as above and below the beam. This system provides detection of scattered electron with the energy loss of 16-50%. The orbit radial displacement is foreseen after beam storage for detection of electrons with smaller energy losses.

Scintillation counters and proportional chambers placed above and below the beam are also used for luminosity measurements by elastic scattering at small angles. Besides that, luminosity monitoring will be performed by double Bremsstrahlung by means of total absorption Čerenkov counters.

Fig.3. 4. 5 show the magnetic detector MD-1. It is a closed-type rectangular solenoid with a useful volume of 9.5 m^3. Starting from the interaction region the magnet contains: vacuum chamber, coordinate chambers, scintillation counters, gas Čerenkov counters and shower-range chambers. Muon chambers are placed beyond the magnet winding, inside and beyond its yoke.

Trajectories of charged particles and their momenta are measured by 38 coordinate chambers covering a solid angle of $0.8 \times 4\pi$.

To measure the particle range, detect γ -quanta and determine their energy shower-range proportional chambers with stainless steel plates are used. Identification of electrons with momenta greater than 500 MeV/c is also carried out by shower-range chambers. At lower energies gas Čerenkov counter are used.

By measuring ionization losses in the scintillation counters and ranges in shower chambers muon-hadron separation is performed. Muons with the energy greater than 700 MeV penetrate the winding and are detected by muon chambers. The threshold of Čerenkov counters is 700 MeV/c for pions and 2.5 GeV/c for kaons. Kaons with momenta less than 700 MeV/c are identified by ionization losses in the scintillation counters. The scintillation counters are also used for cosmic ray rejection by the time-of-flight information. The main parameters of MD-1 are presented in Table II.

3. Description of the detector elements

3.1 The magnet

The main magnet of the detector is a closed-type solenoid (Fig.3) with the external size of $2.9 \times 5.7 \times 4.4$ m^3 and the useful one of $2.3 \times 2.3 \times 1.8$ m^3. Such a magnetic design ensures the uniform field. Copper coils of 40 t and 32 cm thick consist of two parts between which a vacuum chamber is placed. Magnetic flux returns back by steel yoke of

400 t weight. The yoke has holes for the photomultipliers of the scintillation and Čerenkov counters. Supplied power at 16 kGauss is equal to 3.5 MW. The magnet is mounted on the mobile platform.

Table II.

Main parameters of MD-1

Magnet		
Field volume	$9.5\ m^3$	
Maximum field strength	16 kGauss	
Proportional chambers		
Coordinate	$(0.86 \times 0.9\ m^2)^*$	38 planes
Shower-range	$(1.7 \times 0.8 \times 0.25\ m^3)^*$	14 x 10 -"-
Muon	$(1.35 \times 1.7\ m^2)$	40 x 2 -"-
Scattered electrons	$(0.25 \times 0.6\ m^2)$	8 -"-
Electronic channels		16.000
Gas Čerenkov counters		
Number $(1.55 \times 0.6 \times 0.17\ m^3)$	8	
Threshold for pions (n=1.02)	700 (MeV/c)	
Scintillation counters		
Number $(0.6 \times 0.6\ m^2)^*$	38	
Momentum resolution		
at H = 16 kGauss	$\sigma_p/p = 4p$ (GeV/c)%	
Solid angle		
Particle detection	$0.85 \times 4\pi$	
with Čerenkov counters	$0.6 \times 4\pi$	

(*) active area of the largest unit

3.2 Vacuum chamber

In Fig.6 the general view of the vacuum chamber is shown. It is a complicated construction supplied with the synchrotron radiation (SR) receivers, vacuum pumps, various exit windows. The principal particularities of the construction are connected with the necessity of the escape and absorption of SR created in the main, additional bending magnets and in the neighbouring to an interaction region bending magnets of the storage ring. This problem is considered in detail in /3/.

The inteaction region is surrounded by the cylindrical part 40 cm in diameter and 1 m long. The thickness of pipe walls is 3 mm of duraluminium. Further from the interaction region the chamber has a rectangular section. Near the first lens the horizontal size of the chamber reaches 2 m. There is an exit foil for escape of electrons in the scattered electron tagging system and luminosity measurement by small angle elastic scattering. At the end of the vacuum chambers additional receivers are placed with the holes for escape of SR beams. The special mobile collimators protect the detector from the radiation reflected from receivers. The scattered electron tagging system is separated from the receivers with the tungsten partition.

A central part of the vacuum chamber placed in the main magnet is partitioned off with latches and is moved together with the detector.

To provide high vacuum in the interaction region the magnet-discharge pumps and titanium sprayers are placed in vacuum chamber. To look after the beam position probes are fixed. In addition probes permit to get bremsstrahlung and monochromatic γ -quanta.

3.3 Coordinate system

The function of the coordinate proportional chambers is to track the charged particles and measure their momentum. The layout of the chambers is shown in Figs. 4, 5.

Maximum size of the chambers is 0.86 x 0.9 m^2. The anode planes are winded with tungsten wires of 28 μm in diameter /2/. Wire spacing of momentum measuring chambers is 2 mm and of that measuring vertical coordinate 4 mm. All the chambers are placed in two vacuum-tight boxis which are pumped out and filled with working gas mixture: Ne(He)+8%Ar+20%CO_2+ +3%C_2H_5OH or Ar+20%CO_2. The thickness of the entrance windows from the interaction region side is 1 mm Al.

For a protection from synchrotron radiation the tungsten foils of 5 cm wide will be placed between the beam pipe and the extrance window of the coordinate chambers. The thickness of the foil is chosen depending on the storage ring energy /3/.

The solid angle with the momentum analysis for a single particle is 0.4 x 4π . The momentum resolution is $\delta p/p = (3\div5)p$ (GeV/c)% at H = 16 kGauss. For the multi-prong events the interaction point may be found and the analysed solid angle increases up to 0.6 x 4π. In additional solid the momentum resolution is 5÷7% while the resolution of the system from the extrenal side from the beam reaches 1.0 x p (GeV/c)% at H = 16 kGauss, $p \geq 1.0$ GeV/c.

3.4 Shower-range chambers

The shower-range chamber system consists of 14 units placed inside the magnet. These chambers cover the solid angles of about 0.8 x 4π . One unit of the shower-range chamber is "sandwich" of a proportional chamber and stainless steel plates /2/. The plates are spaced with the gap of 10 mm and serve as cathode planes. The plate thickness is 13 mm, the maximum size is 1.75 x 0.81 m^2, flatness does not exceed 0.25 mm. Ten chambers of one unit are placed in stainless steel box which is a supporting construction of the unit and gas-tight box for gas filling.

The anode wires of neighbouring planes are wounded perpendicularly to each other with wire spacing of 4 mm. Each chamber plane is provided with 16 channels of electronics for positron measurements. Besides, the common signals from each plane are outputed which are proportional to energy loss in the chamber. Expected energy resolution of shower-range chamber is $\delta \approx 60/\sqrt{E(GeV)}$% . Range measurements provide π, μ separation.

3.5 Muon chambers

Muon chamber system consists of 40 units with the useful area of 2.3 m^2 /2/. In one unit two proportional chambers are placed with perpendicular wires. Each box lid is the supporting construction of one of the chambers. The anode wires are wounded with 4 mm step. For every plane 16 channels of electronics are used. The chamber operates with the gas mixture Ar + 20% CO_2 in the blowing off regime.

The muon chambers are placed beyond the magnet winding (t = 420 g/cm^2), inside the yoke (750 g/cm^2), beyond the yoke (1250 g/cm^2) and also above and below the magnet (1000 g/cm^2).

3.6 Electronics of proportional chambers

Electronics is based on integral amplifier - shapers /4/ in the non-magnetic performance with 1 mV sensitivity and input resistance of 1.3 kΩ . Amplifiers-shapers are placed inside the vacuum-tignt boxes of the chambers. An output signal of standard shape with a pulse height o.5 V is transmitted by twicted pair cable 28 m long to a logical part installed in the detection control room. Electronics on the coordinate chambers is grouped in modules 64 channels each, while for shower-range and muon chambers the module has 16 channels. The module of shower-range chambers has the adder linear output.

The logical part of electronics contains a delay univibrator for 500 nsec, coincidence circuit and memory flip-flop. A standard crate contains 960 channels, a plate of fast "OR" signals, a plate for one-line interrogation by "MOR" system and preparing data for a processor. Creation of a fast "OR" signal shaped from the leading edge of a univibrator pulse allows to include any chamber part in the trigger, as well as to organize coincidence or another logical operation between the electronics channels inside the crate.

3.7 Scintillation counters

A system of coordinate chambers is surrounded by 24 scintillation counters placed on sides of a cube of 1.2 m. Each side contains 4 counters with a size 0.6 x 0.6 m^2. A solid angle of the counters is $0.9 \times 4\pi$. The counters are used for cosmics rejection by time-of-flight as well as for measuring ionization losses. NE-110 plastic 1 cm thick and 56 DVP-photomultipliers (one per counter) are used. Photomultipliers are located in the holes of the yoke ans surrounded by magnetic screens. When a minimum ionization particle passes through a scintillator about 50 photoelectrons are produced at the photocathose, the pulse height distribution having FWHM $\approx$ 30%. According to calculations counters will have time-of-flight resolution about 1 nsec (FWHM) if information about the point where it hits a scintillator is used.

3.8 Gas Čerenkov counters

After coordinate chambers and scintillation counters 8 threshold gas Čerenkov counters are placed with a solid angle of $0.6 \times 4\pi$. Counters are filled with ethylene with a pressure of 25 atm. A refraction index n = 1.02 corresponds to a threshold value of a relativistic factor γ = 5. Counters allow separation of electrons from muons up to momenta 0.5 GeV/c and from pions up to 0.7 GeV/c, π and K -mesons are separated in the momentum range 0.7-2.5 GeV/c.

A counter is shown in Fig.10. It consists of one piece frame and 2 lids tightened by titanic studs. Lids are made of the aluminium allay 2 cm thick. Internal surface of the counter is covered by diffuse-reflecting paint with high reflectivity. The light from the volume is collected to 4 photomultipliers through quartz window and hollow mirror light-guides. Their large length is connected with magnetic shielding of PM placed in the yoke holes. Detection efficiency for particles with velocity more than a threshold one is 99%. For $e^{\pm}$ this value is 2-3% less due to bremsstrahlung and annihilation in the material of a front lid. Before threshold detection is mainly due to Čerenkov light of δ -electrons, ethylene scintillations being small. Such an efficiency depends on the particle velocity and doesn't exceed 5%.

3.9 The electron tagging system

The scattered electron tagging system (SETS) is placed before nearest lenses from both sides of the interaction region (Fig.2) It consists of proportional chambers and scintillation counters placed from the inner side of the orbit and also above and below the beam. The maximum angle accepted by SETS is ±25 mradn on vertical and $^{+25}_{-100}$ mradn on radial direction. The minimum is 12 mradn on vertical and 15 mradn on radius. The electrons scattered forward are detected with a relative energy loss x = 16÷50%.

x_{min} is restricted by storage ring aperture. The orbit radial displacement is foreseen for detection of electrons with smaller energy losses. In this case at the energy 3.5 GeV x_{min} = 10%.

SETS consists of 4 proportional chambers from both sides from the interaction region. 3 chambers measure simultaneously radial and vertical coordinates, while the fourth one - the oblique coordinate. The chambers have "C"-like view with the size of 60 x 25 cm^2, the distance between edge chambers is 70 cm. The radial coordinate is measured by inductional chambers with a cable delay line, the vertical and oblique - by signals from anode wires with 2 mm spacing. A spacial accuracy of inductional chambers is $\sigma \approx 100\,\mu m$.

Scintillation counters serve for time-of-flight rejection of background as well as for luminosity measurements by small angle scattering.

The accuracy of measuring the energy of scattered electrons is determined by multiple scattering in the exit window, chamber resolution and beam sizes. Their contribution to σ_E/E is (%):

exit window scattering	$(20/E_0)\sqrt{t}$
chamber resolution	$33E\,\sigma_c/E_0$
radial beam size	$0.09E$
longitudinal beam size	$4(\theta_r E/E_0 - 3\cdot10^{-4}(1-E/E_0)\sigma_\ell)\sigma_\ell$

where E_0 - the beam energy (GeV), E - the energy of scattered electrons (GeV), σ_c - spacial chamber resolution (cm), σ_ℓ - longitudinal size of the interaction region (cm), θ_r - scattered electron angle projection to the orbit plane (radn), t - exit window thickness (rad. units).

Minimum thickness of the exit window is determined by a thickness of the absorber nenessary to protect from SR /3/, i.e. 30 μm of tungsten at 3.5 GeV and 400 μm at 7 GeV. Scattering contributes to resolution by 0.7% and 1% at 3.5 GeV and 7 GeV, respectively. Altogether these factors result in $\sigma_E/E \approx$ 1% at 3.5 GeV and 1.3% at 7 GeV.

3.10 Luminosity monitoring system

Luminosity monitoring will be carried out by two processes: double Bremsstrahlung and elastic scattering at small angles.

In the first case for the γ -quanta detection two total absorption Čerenkov counters are used. The counter length is 1.28 m (10 X_0), diameter 0.6 m (4.5 X_0), energy resolution $\delta = 5/\sqrt{E\,(GeV)}$%. Accidental coincidence due to single Bremsstrahlung whose relative fraction is proportional to luminosity result in background for double Bremsstrahlung. This method is reasonable at luminosities less than 10^{29} $cm^{-2}sec^{-1}$. The detection cross section for double Bremsstrahlung is $\sim 3\cdot10^{-28}$ cm^2.

High luminosities will be measured by small angle ($\sim 1°$) scattering in scintillation counters placed before the lenses (Fig.2). From each side a system has 4 thin scintillation counters, behind them a tungsten convertor and 2 scintillation counters of somewhat larger size to reduce background due to "soft" particles. This system ensures compensation during beam displacements or inclinations. The correlated background can be excluded by using time-of-flight. The detection cross-section is $\sim 10^{-27}/E^2$ (GeV) cm^2. At 7 GeV and 10^{29} $cm^{-2}sec^{-1}$ the counting rate is 2 Hz, i.e. sufficient for luminosity monitoring.

3.11 Triggering system

Coordinate, shower-range chamber as well as scintillation counters are included in a fast triggering. Electronics of proportional chambers allows by using output pulses of fast "OR" to arrange coincidences between the chambers or their parts or to switch it off. Chambers are grouped into units. For trigger two units must be fired, at least, one of them in the upper half of the detector, while another in the lower one (or in the external and internal orbit sides, respectively). This combinations are chosen to decrease the number of double triggering due to a single particle lost from the beam.

In a system of coordinate chambers one unit contains two X(Y) chambers and one Z chamber between them. Each triplet is divided by a Z-chamber into upper and lower unit. A signal from the unit enters if one or two X(Y) and a Z-chamber are fired. In the unit of shower-range chambers at least two plates with perpendicular anode wires must be fired.

To suppress cosmic background synchronization with a phase is made by scintillation counters (the same counters measure time-of-flight to be used in the subsequent data processing).

Fast triggering must result in a counting rate not higher than 1 kHz.

3.12 <u>Fast processor</u>

The further data analysis is performed by fast-programmable processor operating on-line /5/. The processor reconstructs particle trajectories, determines whether a trajectory intersects the interaction region. For the events from interaction region the trajectories are continued to Čerenkov counters, shower-range chambers and muon chambers. Using these data the event classification is carried out. Particularly, by this means the reaction channels with large cross-section will be switched off, for example, double electroproduction of electron-positron pairs. The processor will allow to reduce the information stored on the magnetic tape and accelerate further data processing.

4. Possible physical experiments

4.1 Search for new particles

After discovery of ψ and charmed particles as well as evidence for a heavy lepton search for new particles by e^+e^- colliding beams in the region of higher energies is a immediate task. MD-1 allows search for new particles both by energy dependence of the cross-sections and by kinematical analysis of final products as well. To this end the detection system has a large solid angle for detection of charged particles and γ-quanta, is capable of momentum analysis and e, μ, π, K separation by shower-range muon chambers, gas Čerenkov and scintillation counters, A detection cross-section for the reaction $e^+e^- \to$ hadrons is presented in Table 3, assuming that $R = \sigma_{e^+e^- \to h} / \sigma_{e^+e^- \to \mu^+\mu^-} = 6$ at the energy 7 GeV.

4.2 Test of quantum electrodynamics

Experiments on tests of quantum electrodynamics became already traditional. Identification of the processes $e^+e^- \to e^+e^-, \gamma\gamma, \mu^+\mu^-$ will be made by coordinate, shower-range and muon chambers for $\theta \in (15°, 165°)$.

For rejection of cosmics scintillation counters measuring time-of-flight will be used. Detection cross-sections for these processes are shown in Table 3.

4.3 Weak interactions

At the energy of VEPP-4 the possibility arises to begin study of the weak interaction contribution to the process of muon pair production. This contribution results in charge asymmetry of the angular distribution. At 7 GeV the V-A theory predicts 3% asymmetry. To measure this effect an integrated luminosity about 10^5 nb^{-1} is necessary.

4.4 Two-photon processes

Processes of double electroproduction $e^+e^- \to e^+e^- + X$ allow investigation of the reaction $\gamma\gamma \to$ hadrons ($\pi^0, \eta, \varepsilon, X^0, \pi^+\pi^-$ etc.). The magnetic field perpendicular to the orbit creates optimal conditions for detection of particles flying out predominantly at small angles. To detect them the detector is provided by a tagging system for scattered electrons measuring their energy. Changing the beam energy from 1.5 up to 7 GeV good $\gamma\gamma$-luminosity and effective mass resolution in the range 500 MeV - 5000 MeV can be obtained. At optimal energy the detection efficiency for two scattered electrons is 20÷30%, for at least one about 60÷70% and effective mass resolution $\sigma_M/M \approx 0.05$.

Due to perpendicular magnetic field the process $e^+e^- \to e^+e^- + e^+e^-$ gives a large counting rate in the central part of the detector. At 7 GeV the detection cross-section of such events achieves $\sim 3 \cdot 10^{-27}$ cm^2 with slight energy dependence.

Detection cross-sections for some processes and both scattered electrons detected are presented in Table 3.

Experiments on double electroproduction are not planned in the first runs with MD-1.

Table 3

Detection cross-section for MD-1 (nb)

Reaction	2 x 3.5 GeV	2 x 7 GeV	Comments
$e^+e^- \to e^+e^-$	20	5	
$\gamma\gamma$	4.8	1.2	
$\mu\mu$	1.2	0.3	
hadr hadr	7	2	R = 6 at 2 x 7 GeV
$e^+e^- \to e^+e^- + \eta$	0.04	0.025	$\Gamma_{\gamma\gamma}$ = 1 keV
χ_0	0.045	0.03	6 keV
$\chi(2850)$	0.002	0.005	10 keV
e^+e^-	~4	~8	
$\mu^+\mu^-$	~1	~2	
$\pi^+\pi^-$	~0.1	~0.2	point-like

We are sincerely grateful to numerous collaborators and technical staff participating in the detector construction for help and advices.

References

1. V.A.Sidorov, J.Physique 35 (1974), C2-77.
2. V.R.Groshev, G.M.Kolachev, G.D.Minakov, A.P.Onuchin, V.I.Telnov, Yu.A.Tikhonov, Proceedings of International Conference on Proportional Chambers. Dubna, 1975.
3. A.P.Onuchin, Yu.A.Tikhonov, Problems of synchrotron radiation background in MD-1. Report at Meeting on Methods of Experiments with e^+e^- Colliding Beams, Novosibirsk, 1977.
4. S.E.Baru, S.G.Basiladze, V.R.Groshev, M.V.Gusak, M.I.Markus, A.P.Onuchin, G.I.Proviz, Pribory i Tekhnika EKSP, USSR, Novosibirsk, 1977.
5. S.E.Baru, V.R.Groshev, A.P.Onuchin, E.L.Panina, G.A.Savinov, V.A.Sidorov, V.I.Fominykh. Fast processor for MD-1. Report at Meeting on Methods of Experiments with e^+e^- Colliding Beams, Novosibirsk, 1977.

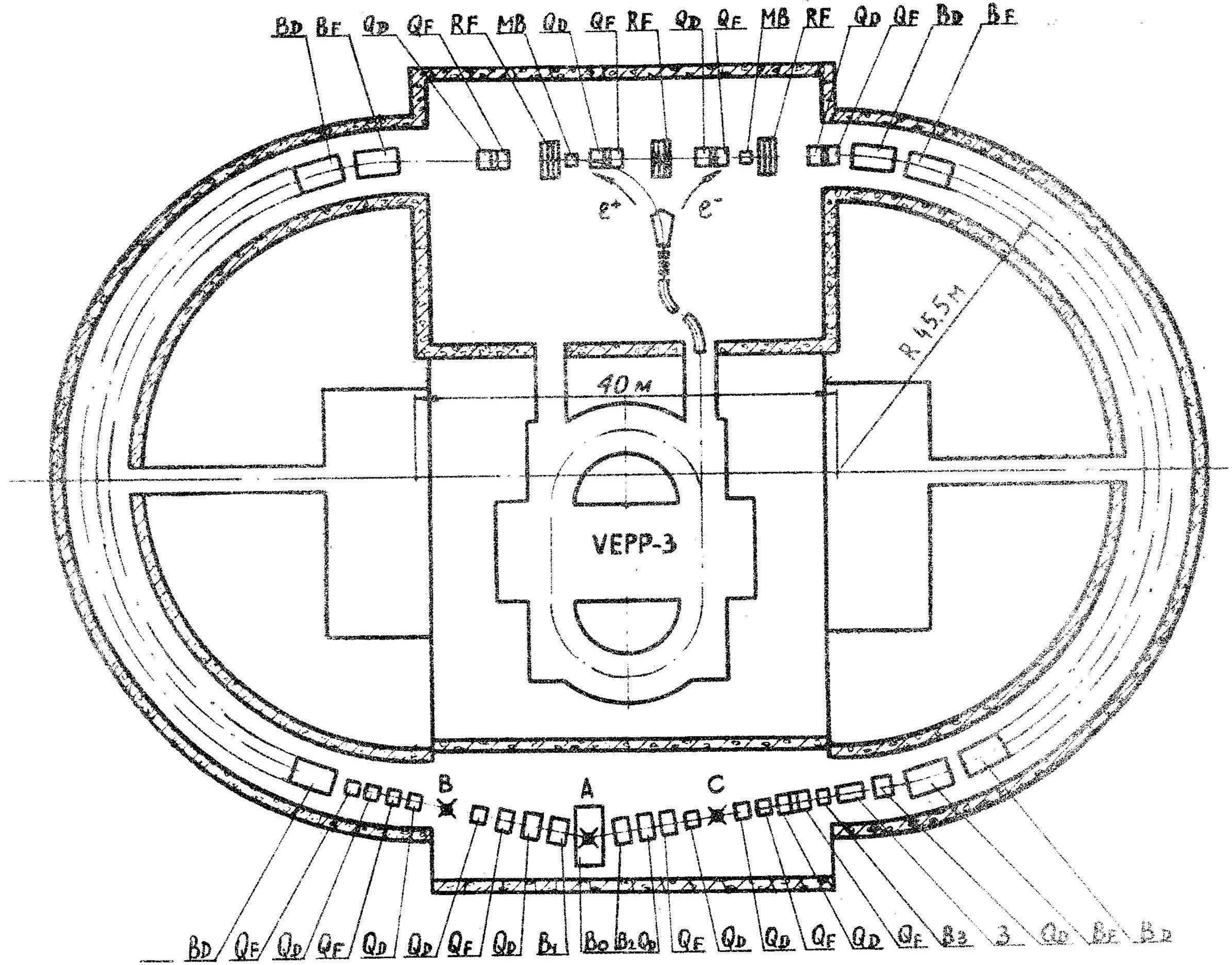

Fig.1 Layout of VEPP-4: B_F, B_D - periodicity elements of ring, Q_F, Q_D - quadrupole lenses, B_1, B_2, B_3 - magnets, B_0 - magnetic detector MD-1, 3 - dampfer, MB - septum magnets, RF - cavity, A, B, C - interaction region.

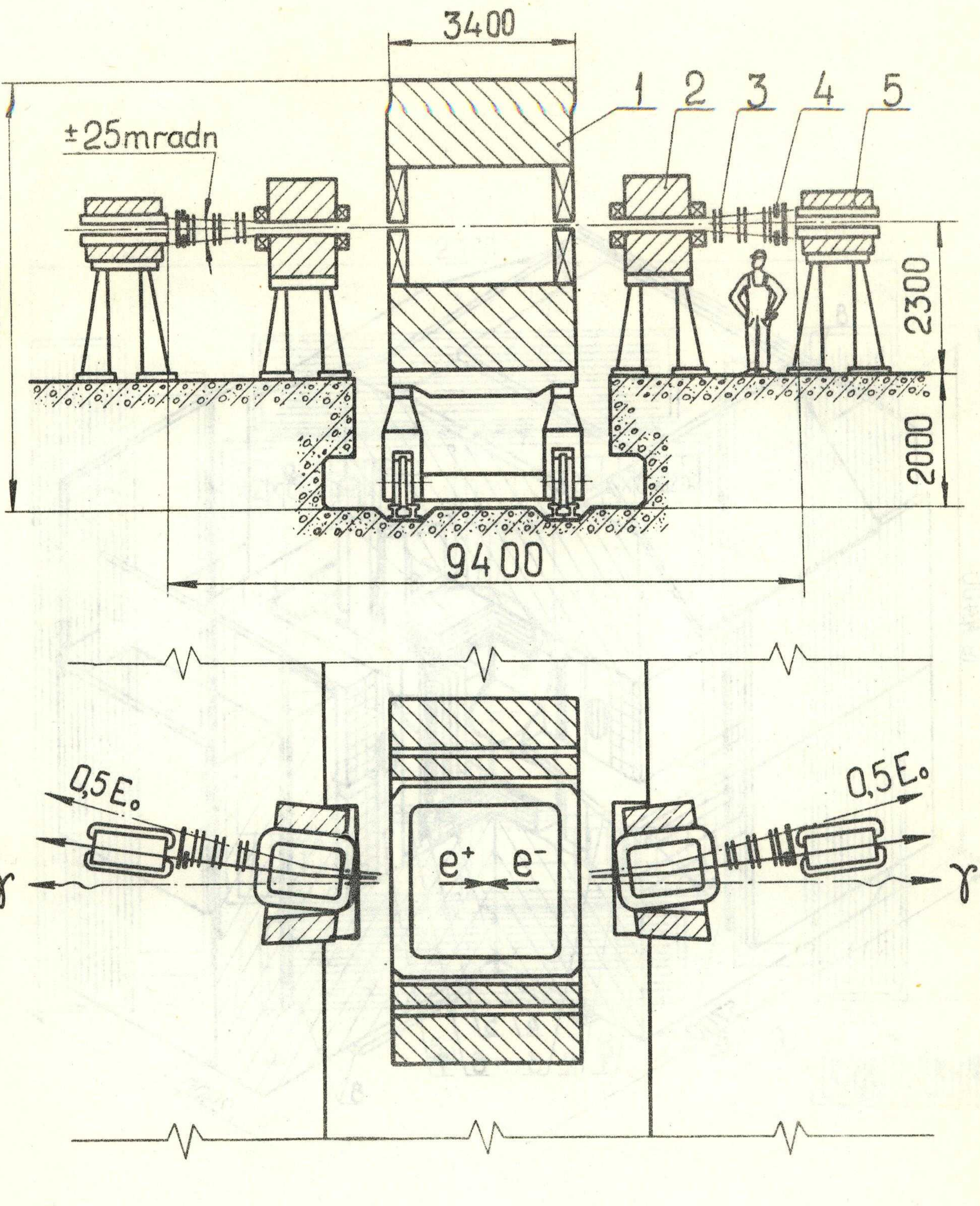

Fig.2 The central interaction region: 1 - detector MD-1, 2 - additional bending magnets, 3, 4 - electron tagging and luminosity monitoring system, 5 - lenses.

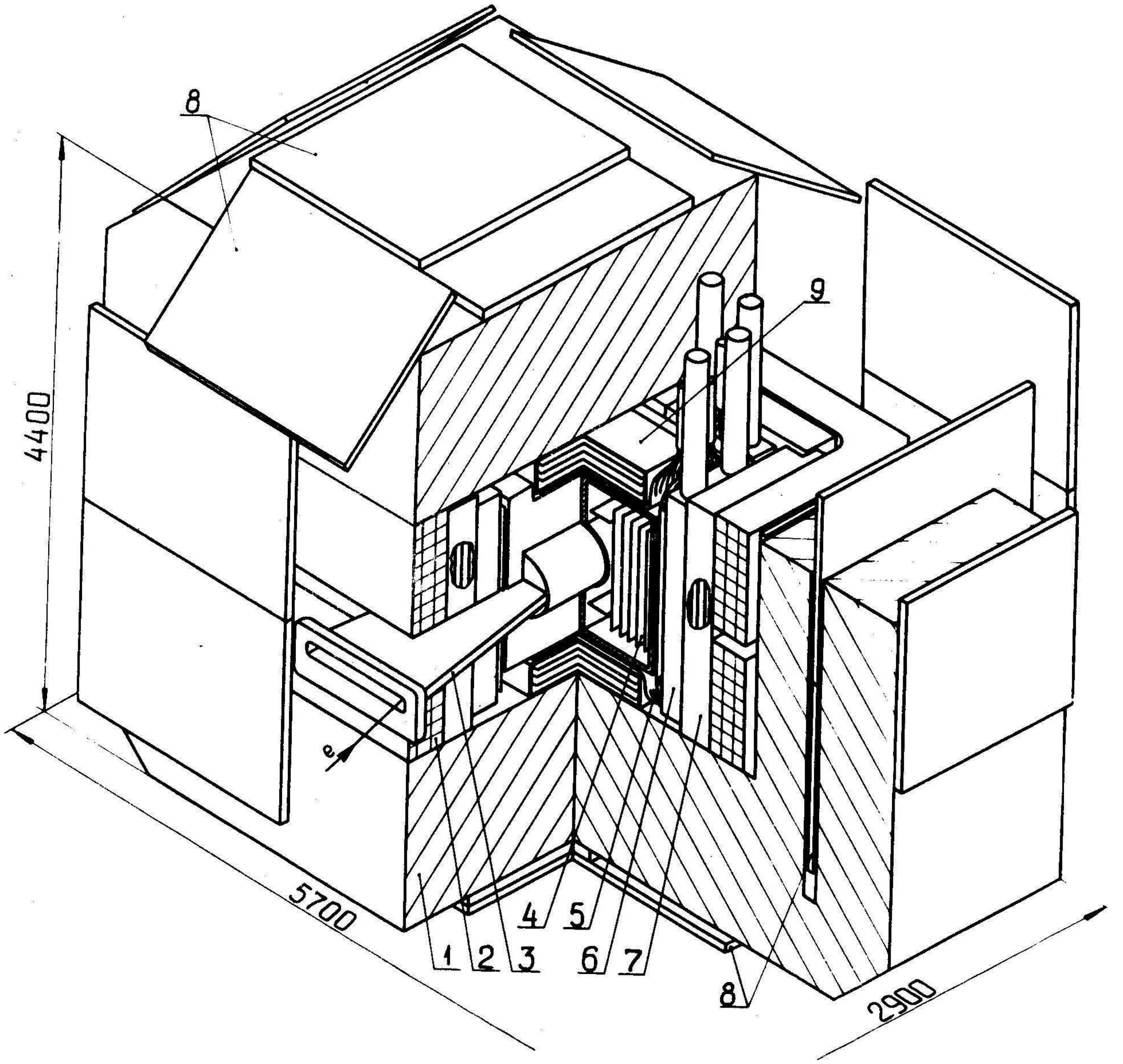

Fig.3 Magnetic detector MD-1: 1 - yoke, 2 - copper winding, 3 - vacuum chamber, 4 - coordinate chambers, 5 - scintillation counters, 6 - gas Čerenkov counter, 7, 9 - shower-range chambers, 8 - muon chambers.

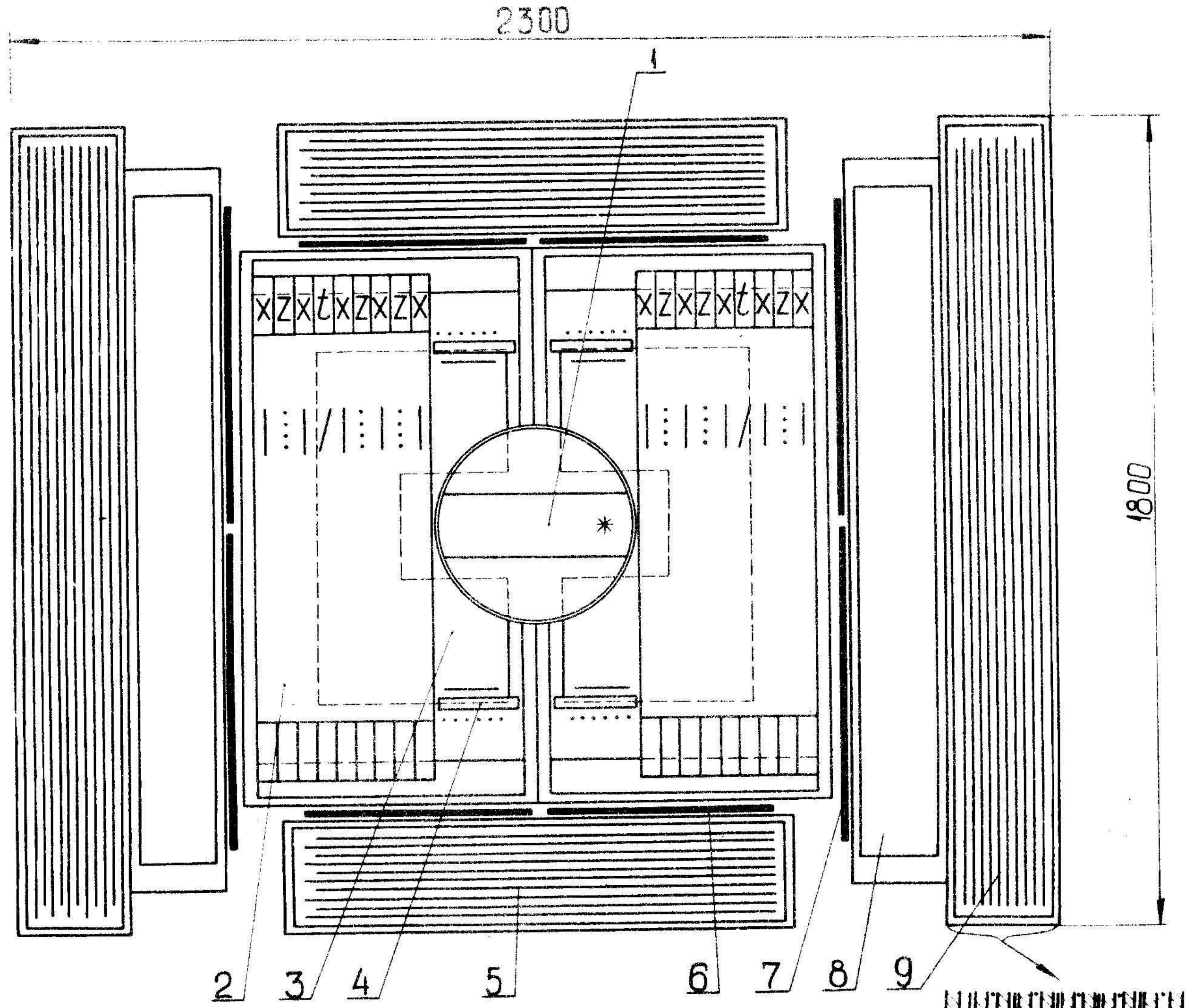

Fig.4 Inner part of detector MD-1, end view:
1 - vacuum chamber; 2,3,4 - coordinate chambers; 5,9 - shower-range chambers; 6,7 - scintillation counters; 8 - gas Čerenkov counter.

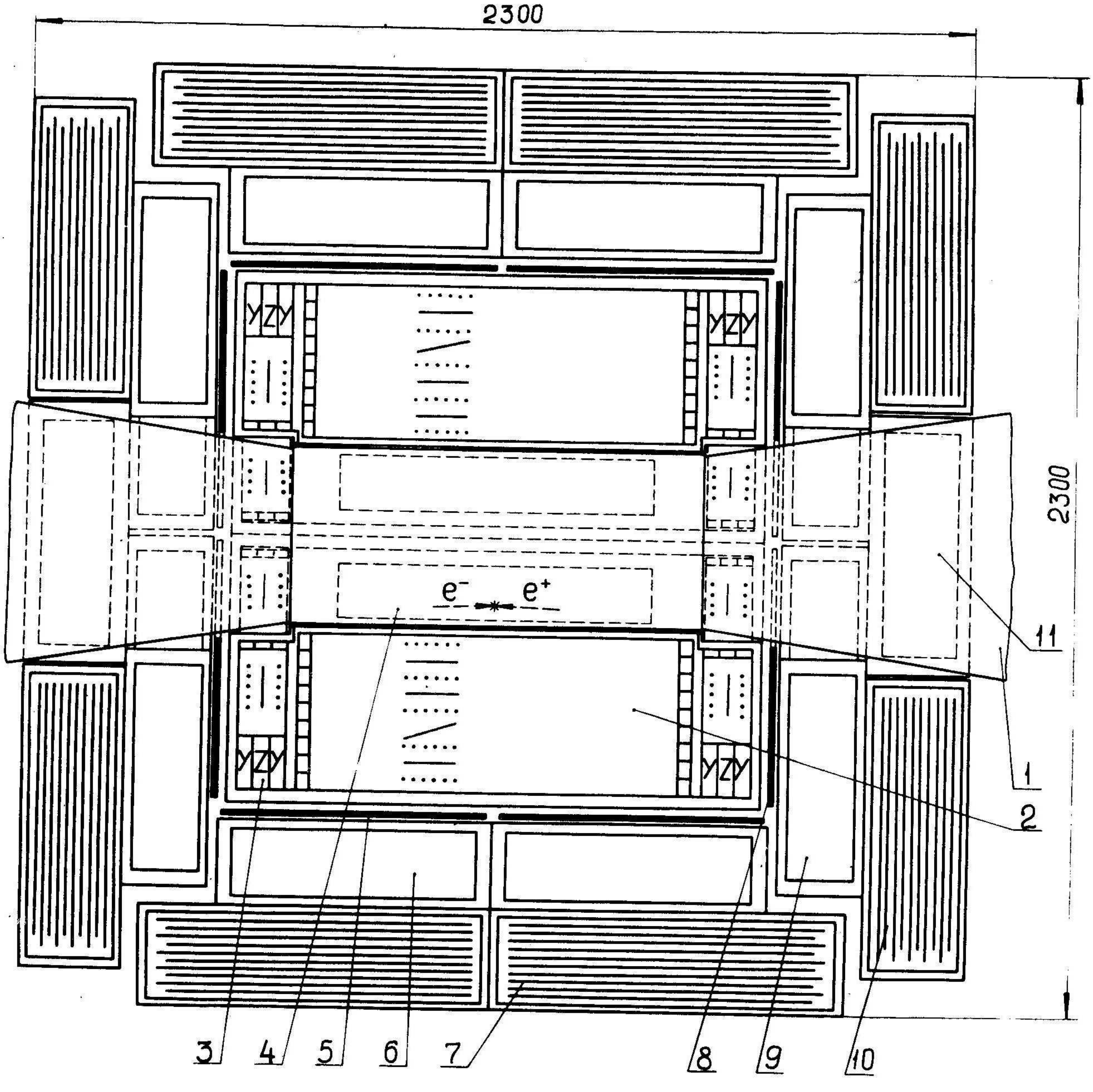

Fig.5 Inner part of detector MD-1, top view: 1 - vacuum chamber, 2-4 - coordinate chambers, 5,8 - scintillation counters, 6,9 - gas Čerenkov counters, 7,10,11 - shower-range chambers.

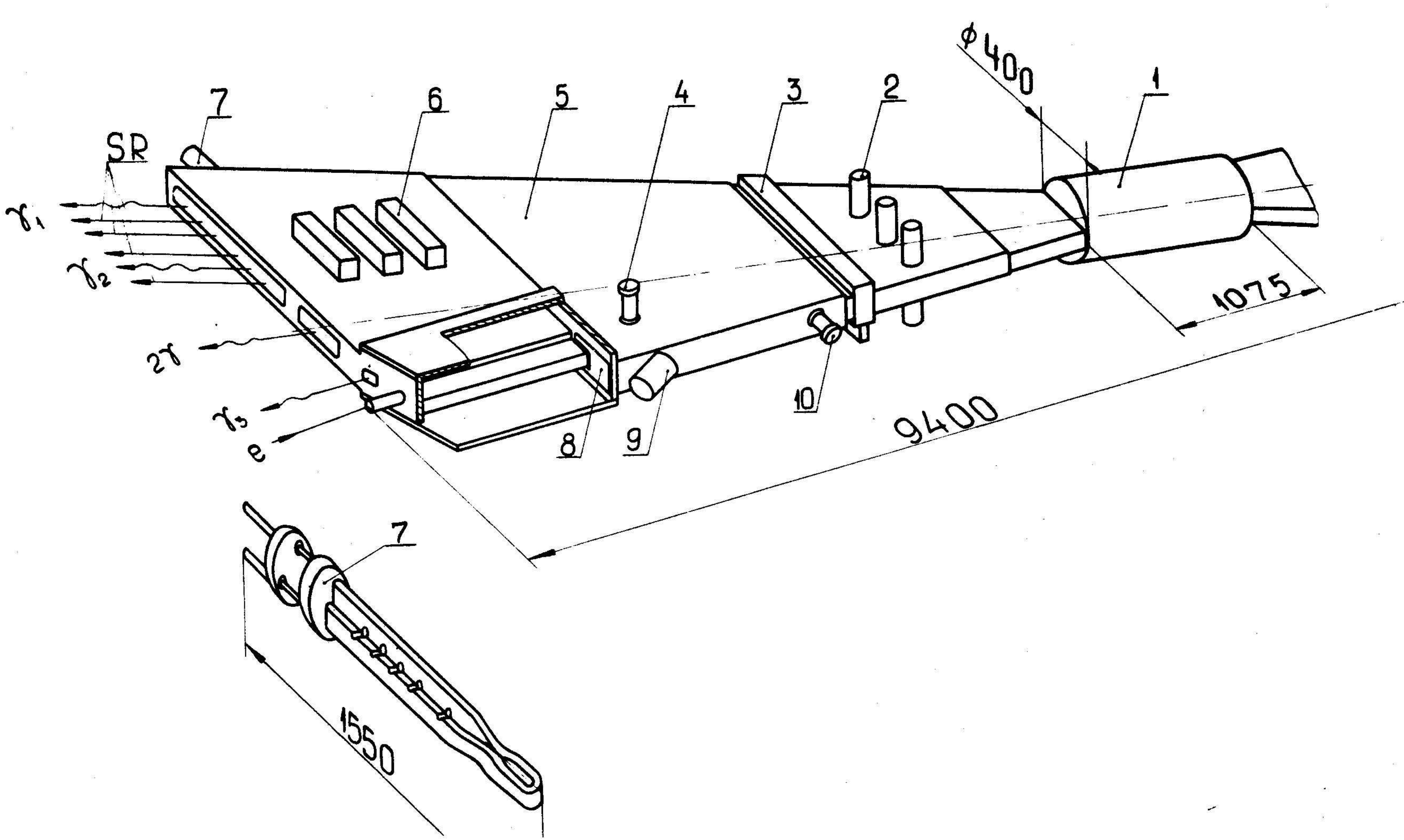

Fig.6 Layout of the vacuum chamber in the central interaction region: 1 - cylindrical part, 2 - mobile collimator, 3 - latch, 4 - vertical probe, 5 - chamber for SR escape, 6 - vacuum pumps, 7 - SR reseivers, 8 - entrance window of electron tagging system, 9 - electron escape for γ -quanta monochromatization,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

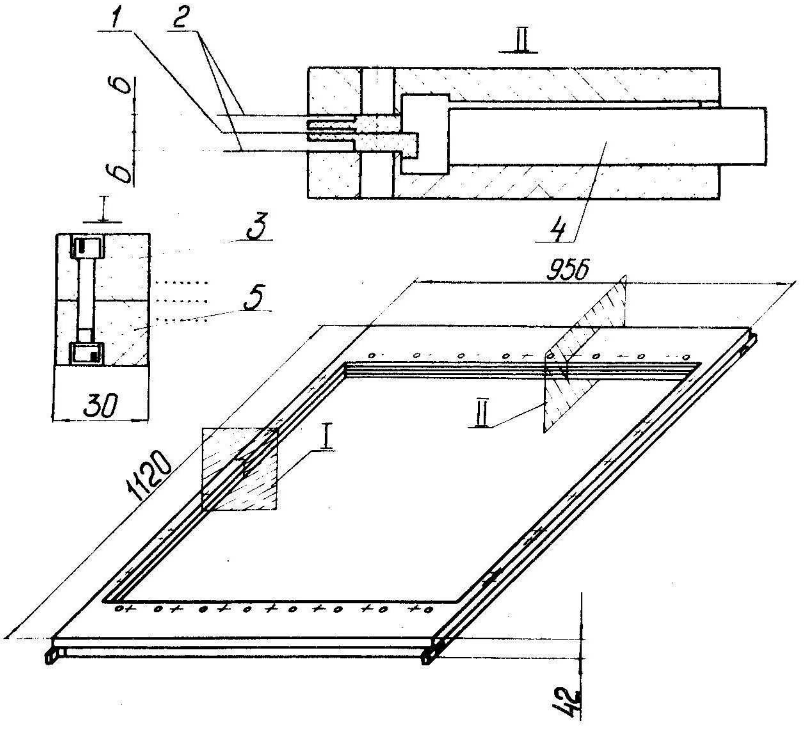

Fig.7 Coordinate chamber:
1 - anode wires,
2 - cathode wires,
3,5 - frames,
4 - chamber electronics.

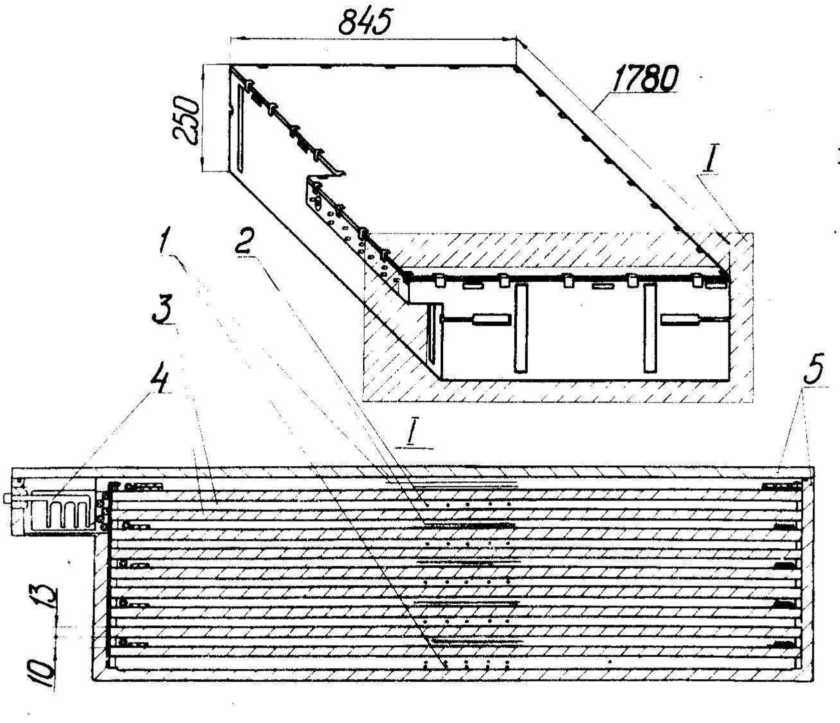

Fig.8 Shower-range chamber:
1 - cathode wires,
2 - anode wires,
3 - stainless steel plates, 4 - chamber electronics.
5-stainless steel box

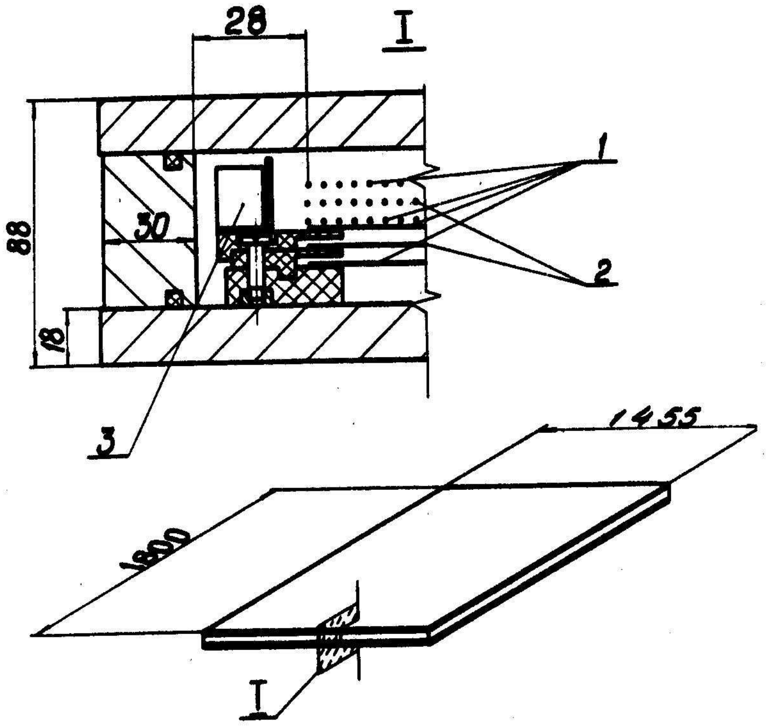

Fig.9 Muon chamber: 1 - cathode wires, 2 - anode wires, 3 - chamber electronics

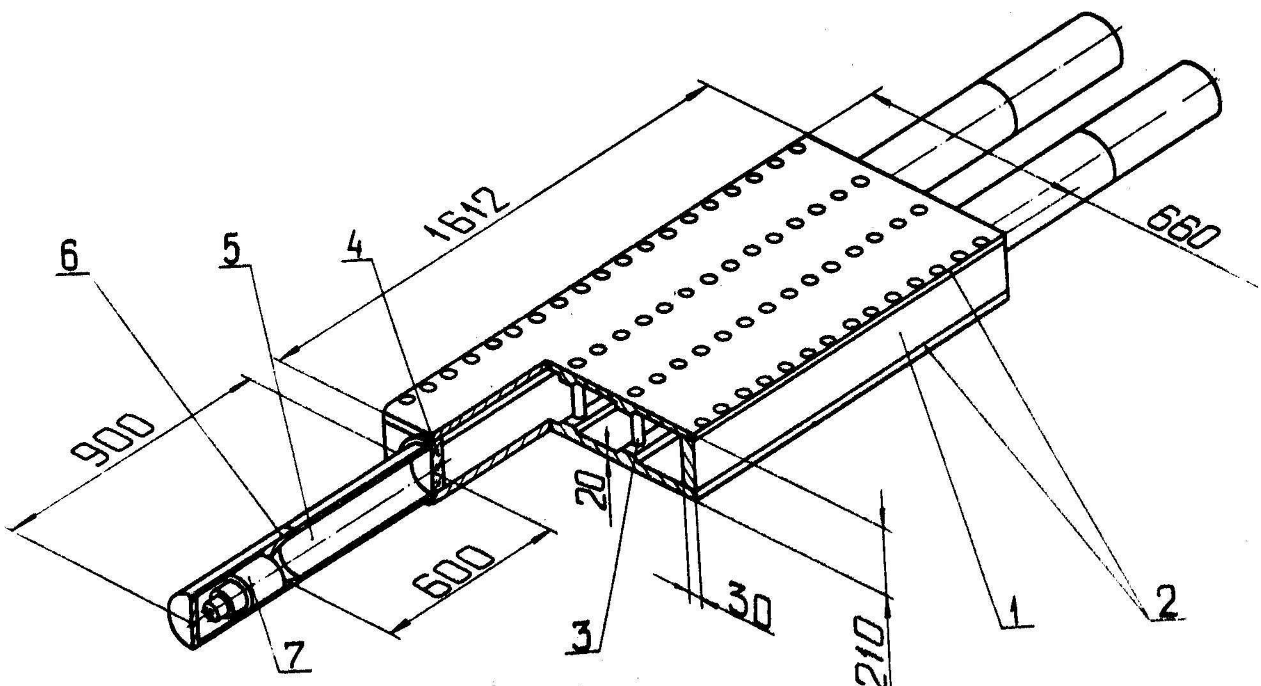

Fig.10 Gas Čerenkov counter: 1 - frame, 2 - lids, 3 - studs, 4 - quartz window, 5 - lightguide, 6 - magnetic screen, 7 - photomultiplier.

Работа поступила - 4 августа 1977 г.

Ответственный за выпуск - С.Г.ПОПОВ
Подписано к печати - 29.УШ-1977г. МН 02967
Усл. 1,9 печ.л., 1,5 учетно-изд.л.
Тираж 250 экз. Бесплатно
Заказ № 75.

Отпечатано на ротапринте ИЯФ СО АН СССР