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Calorimetry of the CMD-3 detector

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Abstract. The CMD-3 detector has been collecting data since 2010 at the e^+e^- collider VEPP-2000 in the Budker Institute of Nuclear Physics. VEPP-2000 uses the novel round beam technique and provides high luminosity in a wide c.m.energy range from 0.32 to 2 GeV. The physics goal of the CMD-3 experiment is a study of the e^+e^- annihilation into hadrons. CMD-3 is a general-purpose detector, which provides high efficiency for both charged and neutral particles. The electromagnetic calorimeter consists of the barrel calorimeter based on liquid xenon and CsI crystals, and the endcap calorimeter based on BGO crystals. The main parameters of the calorimeters are presented.

1. Introduction

VEPP-2000 [1, 2] is an e^+e^- collider at the Budker Institute of Nuclear Physics (BINP) in Novosibirsk, Russia. It operates in a center-of-mass (c. m.) energy range from 0.32 up to 2 GeV. The design luminosity of the collider at 2 GeV c. m. energy is $10^{32} \text{ cm}^{-2}\text{s}^{-1}$. In order to reach this luminosity in a single-bunch mode a novel round beam technique developed at BINP is used. The beam energy is monitored with a precision of $\Delta E/E = 6 \cdot 10^{-5}$ using the Compton backscattering process [3, 4]. There are two interaction points at the collider and two detectors are mounted there: Spherical Neutral Detector (SND) [5, 6] and Cryogenic Magnetic Detector (CMD-3) [7]. Data taking started in 2010. The integrated luminosity collected by each detector during three years of operation is about 60 pb^{-1} . In 2013 the collider operation was stopped for an upgrade of the collider and detectors, and it is planned to resume experiments in 2016.

The physical program [8, 9, 10] includes a measurement of the $e^+e^- \rightarrow \text{hadrons}$ cross sections, a study of the properties of known and a search for new vector mesons, a measurement of $n\bar{n}$ and $p\bar{p}$ cross sections near threshold and searches for exotic hadrons. These tasks require a detector with high detection efficiency for multiparticle events and good energy and angular resolution for both charged particles and photons.

CMD-3 is a general-purpose detector. Its layout is presented in figure 1. The electromagnetic calorimeter is one of the most important systems of the CMD-3 detector. Its main goals are



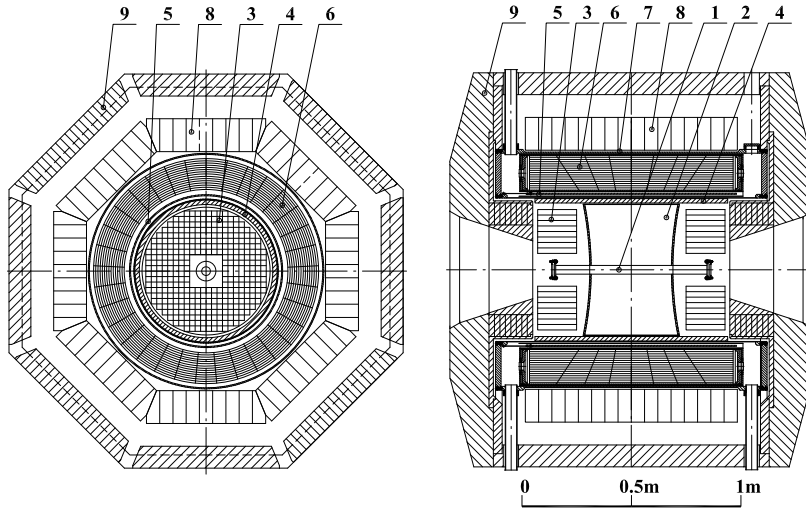


Figure 1. The CMD-3 detector layout.

- 1 – beam pipe,
- 2 – drift chamber,
- 3 – BGO endcap calorimeter,
- 4 – Z-chamber,
- 5 – superconducting solenoid,
- 6 – liquid xenon calorimeter,
- 7 – time-of-flight system,
- 8 – CsI calorimeter,
- 9 – yoke.

measurements of the energy and coordinate of photons, separation of electrons from hadrons and generation of signals for the neutral trigger. The calorimeter of the detector consists of barrel and endcap parts. The barrel calorimeter combines the inner liquid xenon calorimeter (LXe) [11] and the outer one based on CsI crystals [12]. The endcap calorimeter [13] is based on the BGO crystals. The total solid angle coverage of the whole CMD-3 calorimeter is equal to $0.94 \times 4\pi$.

2. General description

The inner LXe calorimeter is a set of 14 ionization chambers with 7 cylindrical cathodes and 8 anodes divided by a 10.2 mm gaps between them. The calorimeter is placed in the same vacuum vessel with a superconducting solenoid to reduce passive material in front of the calorimeter. The electrodes are made of 0.5 mm thin G-10 plates foiled with copper. The conductive surface of anode cylinders is divided into 264 rectangular pads (8 along the Z-axis and 33 in the $r-\varphi$ plane) forming so-called “towers” oriented at the beam interaction point. Pads within one tower are electrically connected. An average tower size is $8 \times 10 \times 15 \text{ cm}^3$. The signals from the towers are used to measure the deposited energy. Cathode cylinders are divided into 2112 strips to provide a precise coordinate measurement together with the measurement of specific energy losses. Each side of the cathode cylinder contains about 150 strips. The strips on the opposite sides of the cylinder are mutually perpendicular. One signal strip consists of four connected 2 mm width strips. Such a semitransparent electrode structure provides charge induction on both sides of a cathode electrode. That allows one to determine both coordinates of the point of photon conversion using the information from one gap only. The design of the LXe calorimeter is described in detail in [11, 14].

Since the LXe calorimeter is rather thin ($5.4 X_0$), it is surrounded by the CsI calorimeter to improve energy resolution. The CsI calorimeter consists of 1152 $6 \times 6 \times 15 \text{ cm}^3$ Na- or Tl-doped CsI crystals assembled in 8 octants. Each octant consists of 9 rows (modules) of crystals. In each octant modules on both sides have special truncated shape in order to avoid gaps between octants. Each module is assembled of 16 counters. The length of crystals corresponds to the thickness of $8.1 X_0$. The total sensitive material thickness of the barrel calorimeter for a normal incident particle is equal to $13.5 X_0$. The thickness of the passive material in front of the barrel calorimeter is $0.35 X_0$ and passive material between LXe and CsI parts of the barrel calorimeter is $0.25 X_0$. The design of the CsI calorimeter is described in detail in [12].

To increase solid angle coverage, the CMD-3 is equipped by the endcap calorimeter. It consists of 680 BGO crystals of $2.5 \times 2.5 \times 15 \text{ cm}^3$ arranged in two identical arrays. The endcap part of the calorimeter covers polar angles from 17° to 50° and from 130° to 163° . The length

of crystals corresponds to the thickness of $13.4 X_0$. The design of this calorimeter is described in detail in [15].

3. Calibrations and resolutions

Several procedures of the calorimeter calibration are used. Calibration with a pulse generator provides a measurement of the pedestal, electronic gain and electronic noise of each channel of the calorimeters. For crystal calorimeters we use cosmic ray particles in special calibration runs. Since the standard CMD-3 trigger does not suppress all cosmic ray events, the experimental data sample contains such events, they are also used for the calibration. This type of calibration is used for both endcap and combined barrel calorimeters. For the LXe calorimeter we use calibration based on e^+e^- elastic scattering events. And for the endcap calorimeter the energy corrections are made using two-photon annihilation process, $e^+e^- \rightarrow \gamma\gamma$, to obtain absolute energy calibration. The calibration procedures for the combined barrel calorimeter is described in [16] and for the endcap calorimeter in [13].

Two-photon annihilation events were used to obtain the energy and spatial resolutions of the calorimeters. The results are shown in figures 2 and 3.

The energy resolution for the barrel calorimeter can be parameterized as $\sigma_E/E = \frac{0.034}{\sqrt{E[\text{GeV}]}} \oplus 0.020$ and for the endcap one as $\sigma_E/E = \frac{0.024}{\sqrt{E[\text{GeV}]}} \oplus 0.023$.

To obtain the spatial resolution of the calorimeters, the distribution of azimuth angle acollinearity $\Delta\varphi = \pi - |\varphi_1 - \varphi_2|$ was used, where φ_1 and φ_2 are azimuthal angles of photons. This distribution was approximated by a Gaussian function, the angular resolution of the calorimeter σ_φ was defined as $\sigma_\varphi = \sigma_{fit}/\sqrt{2}$, where σ_{fit} is the standard deviation of the Gaussian function. The coordinates of most (95%) photons detected in the barrel calorimeter are measured using data from LXe strips with the angular precision of about 0.005 rad, which slightly depends on the photon energy. In this case the angular resolution can be fitted as $\sigma_\varphi[\text{mrad}] = 3.70 + \frac{0.33}{0.25 + E[\text{GeV}]}$. For about 5% of events the conversion point is not reconstructed by strip data and the photon coordinates are determined as a center of gravity of the cluster. For such a case the correction function for the photon coordinates was determined from the simulation. The angular resolution in this case can be fitted as $\sigma_\varphi[\text{mrad}] = 37.0 + \frac{3.6}{0.1 + E[\text{GeV}]}$.

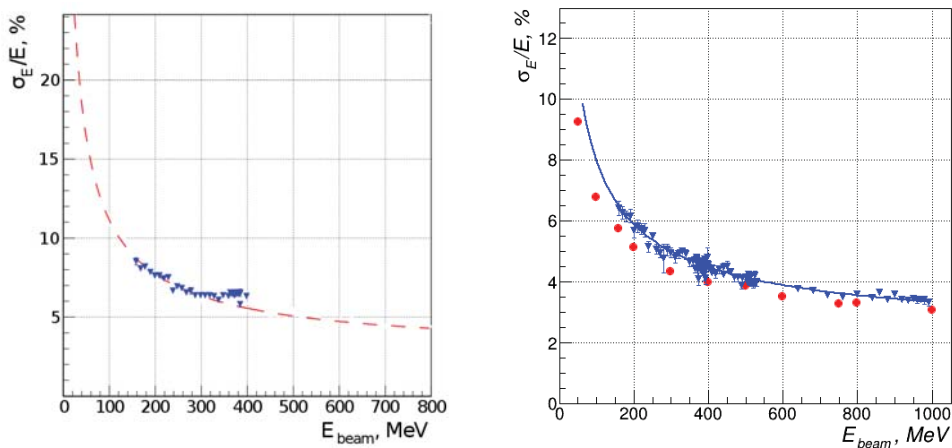


Figure 2. Energy resolution of the barrel (left) and endcap (right) calorimeters for photons: \blacktriangledown — experimental data, — — fit of experimental data, \bullet — MC simulation, - - - — fit of MC simulation.

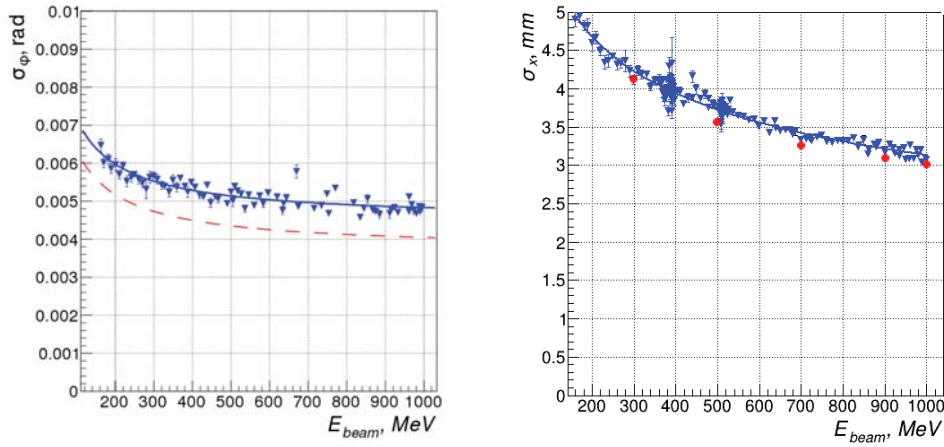


Figure 3. Spatial resolution of the barrel (left) and endcap (right) calorimeters for photons: \blacktriangledown — experimental data, — — fit of experimental data, \bullet — MC simulation, - - - fit of MC simulation.

The spatial resolution of the endcap calorimeter was calculated as $\sigma_x = \sigma_\varphi \cdot Z_0 \cdot \tan \vartheta / \sqrt{2}$, where Z_0 is the distance from the interaction point to the front plane of the endcap and ϑ is a polar angle of the photon. The resolution can be fitted as $\sigma_x[mm] = \frac{3.120}{\sqrt[4]{E[GeV]}} \oplus 0.197$.

4. Conclusion

The calorimeters were installed into the CMD-3 detector and have been exploited in the experimental data taking since 2010. The calibration procedures of the calorimeters have been developed and used during all three physical seasons. The photon energy reconstruction procedures have been developed and applied. The energy and spatial resolutions at 1 GeV have been determined to be 4.5% and 2 mm for the barrel calorimeter and 3.5% and 3 mm for the endcap calorimeter, respectively.

Acknowledgments

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References

- [1] Shatunov Y M *et al.* 2000 *Conf. Proc. C* **0006262** pp 439–441
- [2] Berkaev D *et al.* 2012 *Nucl. Phys. Proc. Suppl.* **225-227** pp 303–308
- [3] Abakumova E V *et al.* 2014 *Nucl. Instrum. Meth. A* **744** 35–40
- [4] Abakumova E V, Achasov M N, Krasnov A A, Muchnoi N Y and Pyata E E 2015 *JINST* **10** no.09, T09001
- [5] Achasov M N *et al.* 2009 *Nucl. Instrum. Meth. A* **598** 31–32
- [6] Achasov M N *et al.* 2015 *JINST* **10** no.06, T06002
- [7] Khazin B 2008 *Nucl. Phys. Proc. Suppl.* **181-182** pp 376–380
- [8] Eidelman S 2006 *Nucl. Phys. Proc. Suppl.* **162** pp 323–326
- [9] Akhmetshin R R *et al.* [CMD-3 Collaboration] 2015 *Phys. Lett. B* **740** 273–277
- [10] Shemyakin D N *et al.* 2016 *Phys. Lett. B* **756** 153–160
- [11] Anisenkov A V *et al.* 2014 *JINST* **9** C08024
- [12] Aulchenko V M *et al.* 2015 *JINST* **10** no.10, P10006
- [13] Akhmetshin R R, Grigoriev D N, Kazanin V F, Kuzmenko A E and Yudin Yu V 2014 *JINST* **9** no.10, C10002
- [14] Anisyonkov A V *et al.* 2009 *Nucl. Instrum. Meth. A* **598** 266–267
- [15] Akhmetshin R R, Grigoriev D N, Kazanin V F, Tsaregorodtsev S M and Yudin Yu V 2009 *Phys. Atom. Nucl.* **72** 477–481 [*Yad. Fiz.* **72** (2009) 512]
- [16] Shebalin V E *et al.* 2014 *JINST* **9** no.10, C10013