Calorimetry at the CMD-3 detector

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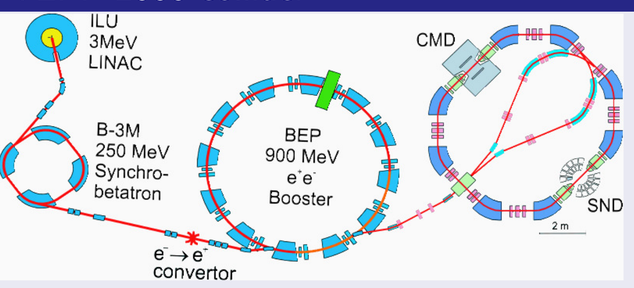
Abstract

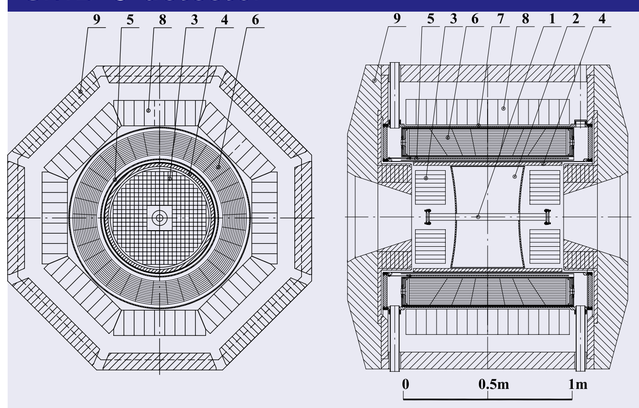
The CMD-3 detector have been operating at the e^+e^- collider VEPP-2000 in the Budker Institute of Nuclear Physics since 2010. CMD-3 is a general purpose detector designed to study e^+e^- annihilation into hadrons in the wide energy range, $E_{c.m.s} = 0.3 \div 2GeV$. The calorimetry at the detector is based on three subsystems: closest to the beam pipe barrel Liquid Xenon calorimeter, outer barrel calorimeter based on CsI scintillation crystals and endcap calorimeter made of BGO scintillation crystals. We will describe the structure of the calorimeters, their electronics and the energy calibration procedures with cosmic particles and using e^+e^- scattering events. The calorimeters characteristics will be also reported.

VEPP-2000 collider



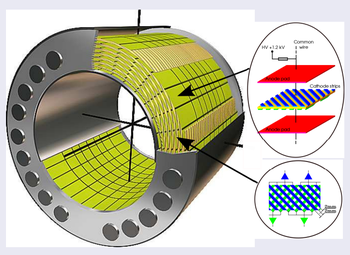
- Design luminosity $L = 10^{32} cm^{-2} s^{-1}$ at 2 GeV c.m.s.
- C.M. energy: 0.3 – 2 GeV
- Time between collisions: 82 ns
- Integrated luminosity: $\sim 60 pb^{-1}$

CMD-3 detector



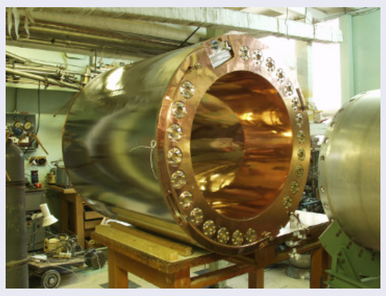
1 - Vacuum chamber
2 - Drift chamber
3 - BGO Electromagnetic calorimeter
4 - Z chamber
5 - CMD3 SC solenoid (13 kGs)
6 - LXe Electromagnetic calorimeter
7 - CsI Electromagnetic calorimeter
8 - Yoke
9 - VEPP-2000 solenoid

LXe calorimeter

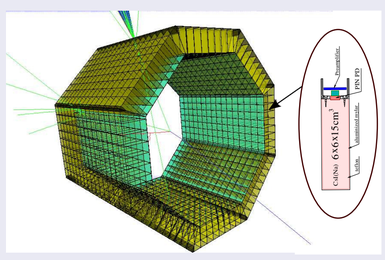


Structure

- Solid angle $0.8 \times 4\pi$
- 8 cylindrical anodes: 264 towers
- 7 cylindrical cathodes: 2112 strips
- Thickness 5.4 X_0



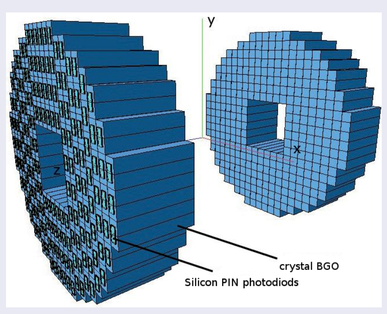
CsI calorimeter



Structure

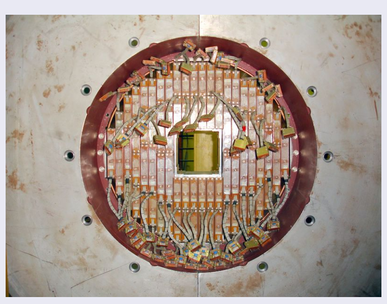
- Solid angle $0.7 \times 4\pi$
- 1152 counters based on CsI(Tl) and CsI(Na) crystals
- Crystal sizes $6 \times 6 \times 15 cm^3$
- Thickness 8.1 X_0

BGO calorimeter



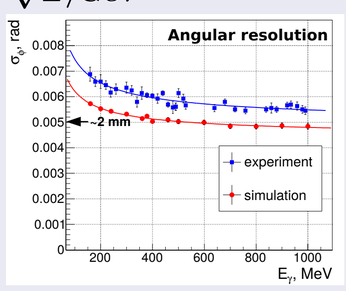
Structure

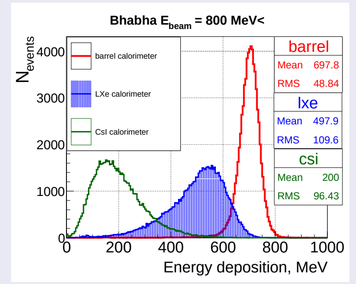
- Polar-angle range 16°–49°, 131°–164°
- Solid angle $0.3 \times 4\pi$
- 680 BGO crystals
- Crystal sizes $0.25 \times 0.25 \times 15 cm^3$
- Thickness 13.5 X_0

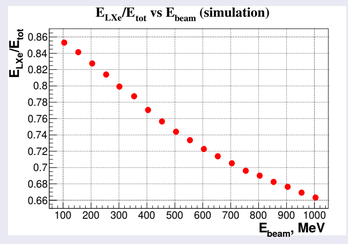


Combined barrel calorimeter

- LXe + CsI calorimeters
- Full thickness 13.5 X_0
- $\sigma_E/E = \frac{0.034}{\sqrt{E/GeV}} \oplus 0.02$
- Passive material thickness between calorimeters 0.25 X_0
- Passive material before LXe 0.35 X_0
- Strip structure of cathode electrodes provides spacial resolution for γ-conversion point of about 2 mm



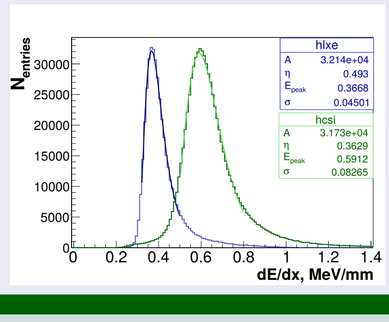




Barrel calorimeter calibration

Cosmic calibration

- Cosmic particle events in experimetal runs
- Tracks in LXe are used
- Path length L_{LXe}, L_{CsI}
- Distribution of $\epsilon = E/L$
- Calibration coefficients $k_i = E^{MC}_{peak}/E^{EXP}_{peak}$



Bhabha calibration

- $e^+e^- \to e^+e^-$ events

$$\chi^2 = \sum_{n=1}^{N} \frac{(E^j_{mc}(\theta,\phi) - \sum E^n_i k_i - E^n_{CsI})^2}{\sigma^2(\theta)}$$

$$\chi^2 \to min$$

$$\frac{\partial \chi^2}{\partial k_i} = 0 \Rightarrow \sum_j k_j Q_{ij} = R_i,$$

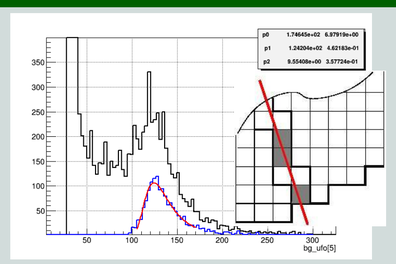
$$Q_{ij} = \sum_{n=1}^{N} \frac{E^n_i E^n_j}{\sigma^2}, R_i = \sum_{n=1}^{N} \frac{E^n_i E^n_{mc}}{\sigma^2}$$

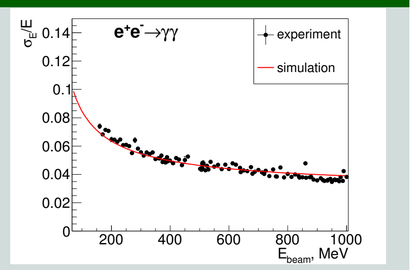
$$k_i = \sum_j R_i (Q^{-1})_{ij}$$

n - event number, i, j - LXe channel indexes

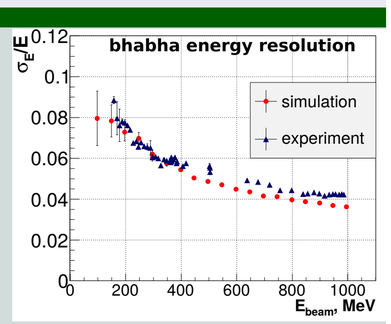
Calibration of BGO calorimeter

- Select events with vertical muons passing through BGO calorimeter
- Select crystals if only adjacent upper and lower crystals are hit

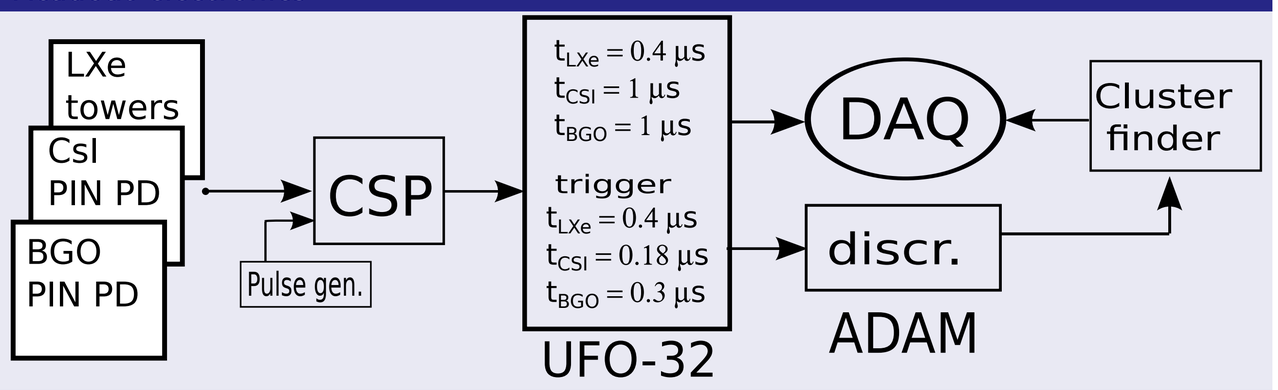




- Preliminar calibration with pulse generator
- Calibration with cosmic particles of LXe and CsI calorimeters
- Calibration of LXe calorimeter using $e^+e^- \to e^+e^-$ events



Readout electronics



Photon energy reconstruction

$E_\gamma = f(E_{dep}, \theta, \phi)$, $E_{dep} = f^{-1}(E_\gamma, \theta, \phi)$ – from simulation of single γ