KEDR detector at VEPP-4M

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Abstract

The status of KEDR detector is presented. KEDR is general purpose detector for experiments at VEPP-4M e^+e^--collider in energy range $2E = 2.0 \div 12$ GeV. All detector subsystems (except aerogel Cherenkov counters) have been installed into detector at VEPP-4M. Some preliminary data were taken at the region J/Ψ meson. The detector and VEPP-4M tuning is in a progress. Preliminary results on detector performance are presented. The future experimental program for KEDR detector is discussed.

VEPP-4M e^+e^--collider ($2E = 2.0 \div 12$ GeV) [1] is a significantly upgraded VEPP-4 machine, which was in operation during 1980–85 and has been destroyed by fire in 1985. Fig. 1 shows a chain of VEPP-4M accelerator complex. The main parameters of VEPP-4M collider are shown in table 1.

Table 1
Parameters of VEPP-4M collider

Energy	2×1.5 GeV	2×5.6 GeV
Number of bunches	2×2	2×2
Maximal currents	5 mA	50 mA
β_x	75 cm	75 cm
β_z	5 cm	5 cm
Bunch crossing	611 ns	611 ns
Maximal luminosity	2×10^{30} $cm^{-2}s^{-1}$	1.5×10^{32} $cm^{-2}s^{-1}$

VEPP-4M is equipped with the single detector — KEDR. The specific peculiarity of VEPP-4M and KEDR is high resolution tagging system for study of two photon processes. The spectrometer for tagging of secondary electrons and positrons is a part of VEPP-4M mashine. VEPP-4M itself and tagging system are in operation since 1995. Already obtained luminosity at $2E = 3.0$ GeV of 0.8×10^{30} $cm^{-2}s^{-1}$ is not far from the design level.

The system for VEPP-4M energy calibration (with precision of 10^{-5}) by resonance depolarization method was installed at VEPP-4M in March 2001. This calibration is needed for high precision measurements of $J/\psi, \psi'$-mesons and τ-lepton masses. During March–June 2001 the procedure of energy calibration was developed. One should say that polarization time in VEPP-4M at $E = 1.5$ GeV is too long ($\tau_p = 100$ hours) and electron beam is polarized in VEPP-3 ($\tau_p = 1$ hour) and then injected in VEPP-4M.

VEPP-4M and buster VEPP-3 operate also as synchrotron radiation sources and there is a wide experimental programm with high resolution tagged photon beam obtained by Compton scattering of laser photons on electron beam at VEPP-4M[2]. The KEDR tagging system is used for photon energy measurement with resolution of $0.5 \div 1.0\%$. The tagging photon beam is used for following experiments:

- Detectors calibration
- Photonuclear phycics
- Study of nonlinear QED processes

The KEDR detector design is shown in Fig. 2 (tagging system is not shown). KEDR was designed to have a high resolution for momentum measurements of charged particles and photon energy as well as good particle identification. The general parameters of KEDR detector are presented in table 2.

Table 2
Major parameters of KEDR detector

Charged tracking:	Vertex Detector (VD), Drift Chamber (CDC)
Spatial resolution	$100\ \mu m\ (X,Y),\ 1\ mm\ (Z)$
Momentum resolution	$\sigma_p/p(\%) = \sqrt{(0.3)^2 p^2(\mathrm{GeV}) + (0.3)^2}$
Calorimetry:	LKr Barrel, CsI endcap
Energy resolution	2.5% at 1 GeV, 6% (LKr), 3%(CsI) at 0.1 GeV
Angular resolution	4(LKr), 9(CsI) $mrad$ at 1 GeV
	4(LKr), 18(CsI) $mrad$ at 0.1 GeV
Hadron identification:	Aerogel counters
Δp for $\pi/K(> 3.5\sigma)$	$0.6 \div 1.5\ GeV/c$
Tagging system:	invariant mass resolution $5 \div 20\ MeV$
Muon system:	spatial resolution 40 mm

KEDR was assembled in March 2000. Aerogel system was not fully ready and only 20 counters have been installed into detector. Some data were taken at J/Ψ region during May – July 2000. The supercondacting coil was sucsessfully tested up to field of 0.7 T. In March 2001 the assembling of LKr external cryogenic system was finished and fill up of the calorimeter is expected in September 2001.

In June 2001 the data taking for high precision measurement of J/ψ and ψ'-meson masses was started.

Below short description of KEDR subsystems and some experimental results are presented.

- Vertex detector based on mylar drift tubes (312 tubes of 10 mm in diameter are arranged in 6 layers, the tubes length is 700 mm) [3]. An example of multihadron decay of J/Ψ reconstructed in vertex detector is shown in fig. 3. The average on drift distance spatial resolution is 100 μm with $Ar + isoC_4H_{10}$ gas mixture (design value is 90 μm). A preliminary result obtained with other gas mixture $Ar + 50\% CO_2$ is shown in fig. 4. The spatial resolution average on drift distance is 110 μm close to design value.

- Drift chamber contains 1600 signal wires arranged in 7 superlayers [4]. Each superlayer is subdivided in drift cells ("SLD" type) with 6 sensitive wires in each cell, drift distance is 3 cm. Drift chamber layout is shown in fig. 5. So called "cool" gas *DME* is used, drift time is 8 μs. A preliminary result on spatial resolution obtained with cosmic rays is shown in fig. 6. A spatial resolution averaged on cell is 150 μm and it is about 1.5 time worse than resolution obtained with prototype. A possible reason which leads to this degradation is temparature gradient across the chamber (due to heating by electronics). This gradient will be decreased by improvement of cooling system.
- Aerogel Cherenkov system consists of barrel and end-cap parts (160 counters in total arranged in two layers, aerogel volume is 800 l) [5]. An aerogel with refraction index of 1.05 is used. Fig. 7 shows the design of the end-cap and barrel counters. The MCP photomultipliers with photocathode diameter of 18 mm working in high magnetic field and wavelenght shifters are used for read-out. Two options for aerogel counters were studied: fill up by aerogel blocks and by crumbs with a size of $\sim 5 \div 10$ mm. Fig. 8 shows the measured dependence of photoelectrons yield on pion momentum. The number of photoelectrons with crumbs is 30% lower but both options provide required π/K separation ($> 3.5\sigma$) in the momentum region $0.6 \div 1.5$ GeV/c. The design with crumbs was chousen because it is more convinient for assembling and contains less material: $13\%X_0$ instead of $18\%X_0$ for option with blocks.
- Time of flight system based on conventional scintillation technique (32 counters in barrel and 64 in end-caps). The obtained time resolution is 230 ps is close to design value.
- Electromagnetic endcap calorimeter consists of 1200 *CsI(Na)* crystalls [6]. Fig. 9 shows energy resolution obtained with a prototype as well as a preliminary result obtained with $e^+e^- \rightarrow e^+e^-$ events at $2E = 3.1$ GeV.
- The barrel electromagnetic calorimeter based on 27 t of liquid krypton was described in detail elsewhere [7]. *LKr* calorimeter is a set of 7200 ionizing chambers with *LKr* gap of 2 cm. Electrodes made from double sided 0.5 mm G10 (2×18 μm Cu). The extensive prototyping of this device shown that the excelent energy and spatial resolution can be obtained. Fig. 10 shows the result of measurement of energy resolution. The designed parameters of KEDR *LKr* calorimeter are listed in table 2.
- Muon system based on 2400 limited streamer tubes (stainless steel tubes with diameter of 40 mm are used) [8]. Muon chambers are placed in iron yoke (see fig. 2) and provide μ/π separation in the momentum region $0.9 \div 5.5$ GeV/c.
- Tagging system for precise measurement of the energy of scattered electrons and positrons in two photon processes is shown in Fig. 11 [9]. For detection of electrons and positrons 1440 stainless steel drift tubes with diameter of 6 mm are used. The energy resolution of the tagging system is about 0.05%, it has been measured using the edge of spectrum obtained by Compton scat-

tering of laser photons on a beam. This energy resolution provides excellent invariant mass resolution for two-photon processes (see Fig. 12).

- The operative luminosity monitoring by process of double bremshtrahlung at zero angles ($e^+e^- \to e^+e^-\gamma$) based on 32 *Pb + scintillator* sandwiches.

The result of scans of J/Ψ-meson region with KEDR detector is shown in Fig. 13.

There is a wide experimental program for KEDR detector in energy region $2E = 2 \div 12\ GeV$.

- Charm physics is still very interesting. KEDR has some advantages compare to detectors already worked in this region: high resolution both for measurements of charged particle momenta and energy of photons as well as good identification system. KEDR can collect $10^8 J/\Psi$ per year (world statistics is 2.5×10^8).
- The precision measurements of total cross section $e^+e^- \to hadrons$ in the region $2 \div 7\ GeV$ is very important for calculation of hadron contribution in muon magnetic momentum. These data are also needed for precise calculation of α_s.
- Precise measurement of τ-lepton mass is very important for calculation of life-time and branchings of τ-lepton. A new high precision measurement of J/Ψ, Ψ' mass is needed for this purpose because these masses are the scale for τ-lepton mass determination.
- Two photon physics with KEDR high resolution tagging system is very promising: precise measurement of total cross section, measurement of two-photon width of *C*-even resonances and etc.
- There are still many unsolved problems in Υ spectroscopy below $B\overline{B}$ threshold.

Some interesting physics results were already obtained at VEPP-4M using KEDR detector tagging system and prototype of *LKr* calorimeter.

- Delbruck scattering of photons in a strong Coulomb field was studied in energy range $140 \div 450\ MeV$: the cross section has been measured (see fig. 14) with an accuracy 10 times better than in previous experiments [10].
- The process of photon splitting in a Coulomb field has been observed for the first time [11]. Fig. 15 shows an example of photon splitting event.

VEPP-4m and KEDR take a shape and very interesting physics is seen in near future.

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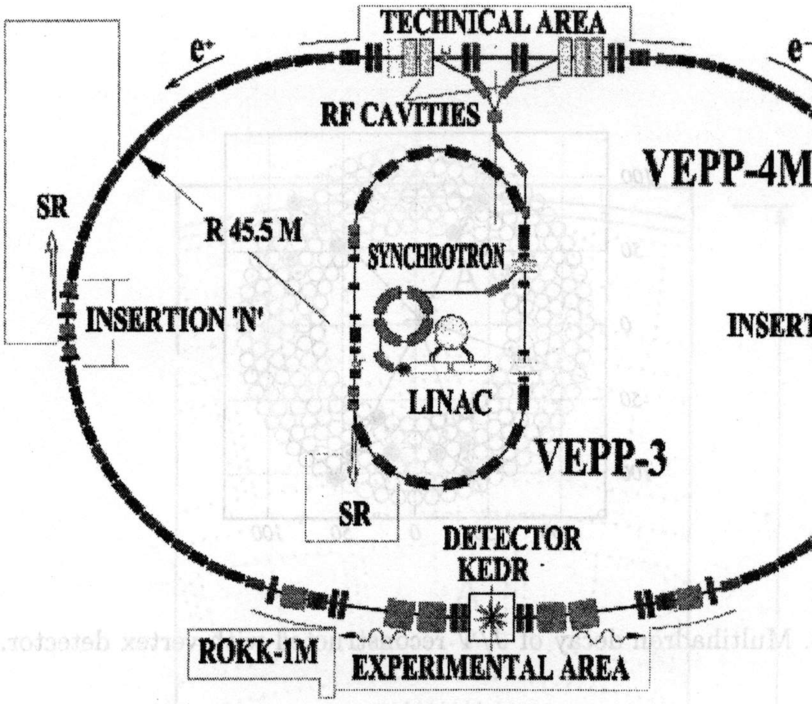

Fig. 1. VEPP-4M electron-positron collider.

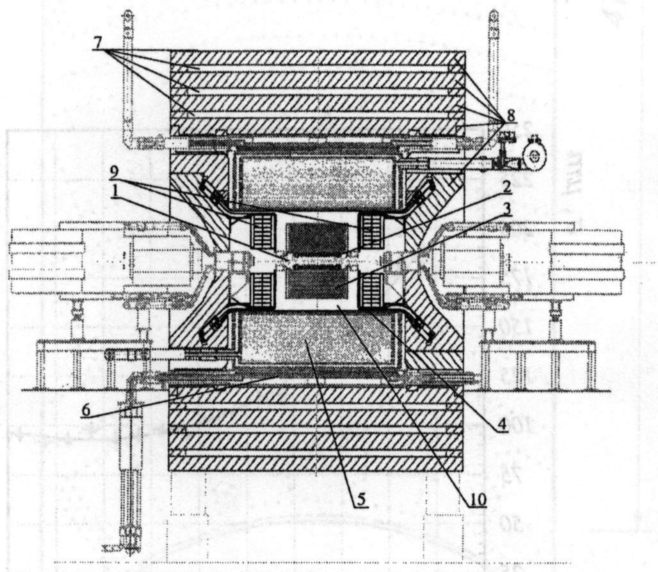

Fig. 2. KEDR detector layout. 1 – Beam pipe, 2 – Vertex detector, 3 – Drift chamber, 4 – Time-of-flight system, 5 – Barrel LKr calorimeter, 6 – Superconductive coil, 7 – Muon system, 8 – Yoke, 9 – Endcap CsI calorimeter, 10 – Aerogel Cherenkov counters.

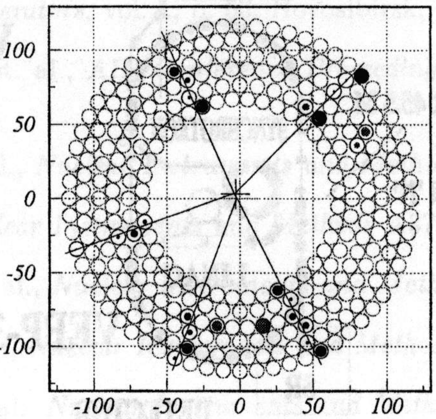

Fig. 3. Multihadron decay of J/Ψ reconstructed with vertex detector.

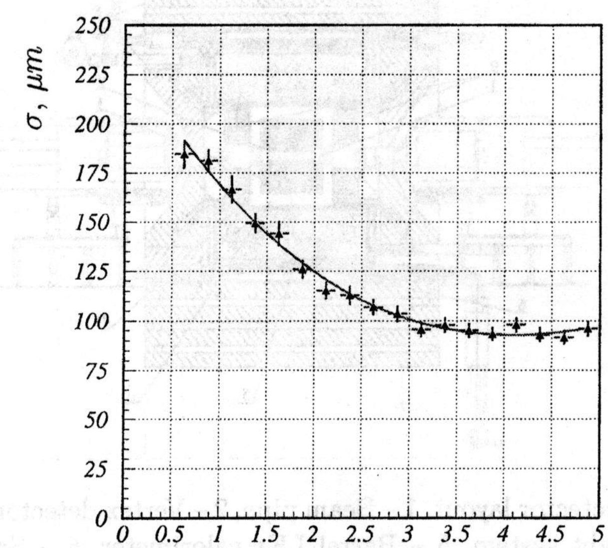

Fig. 4. Spatial resolution of vertex detector.

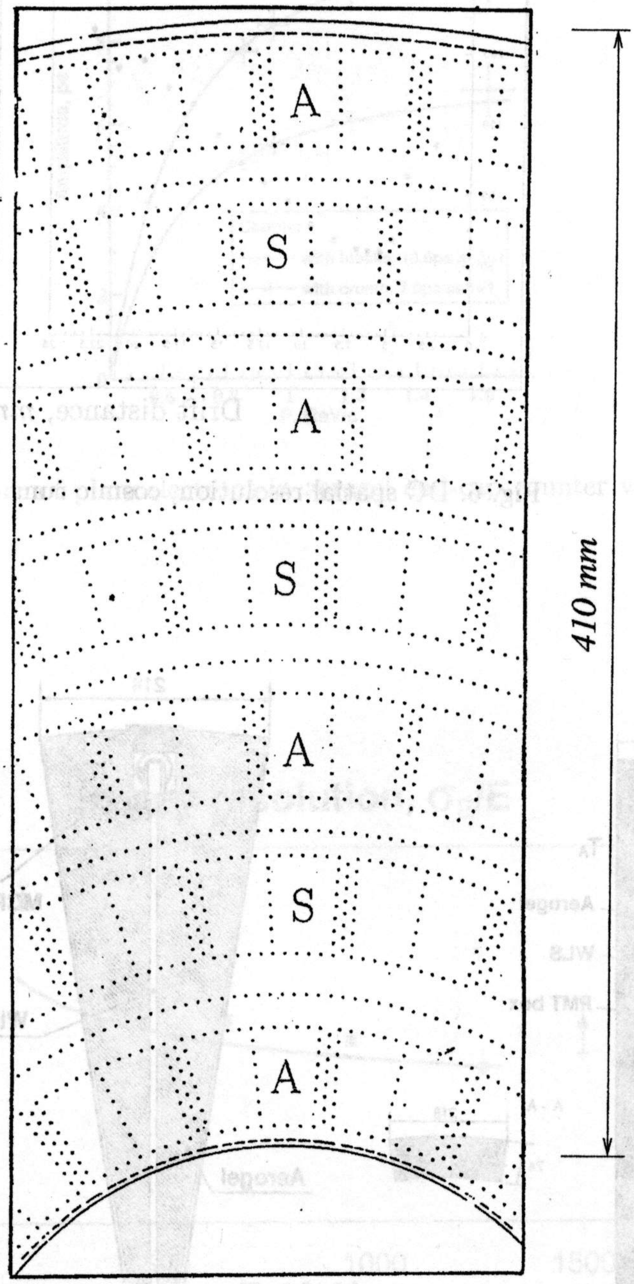

Fig. 5. Overall drift chamber layout. A – axial layers, S – stereo layers.

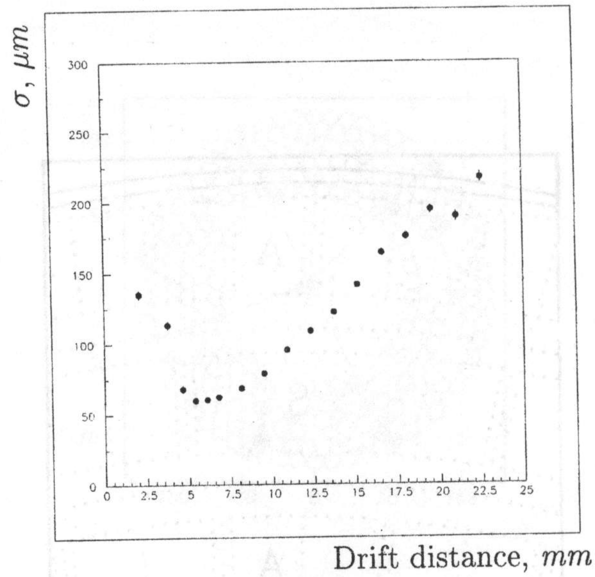

Fig. 6. DC spatial resolution, cosmic run.

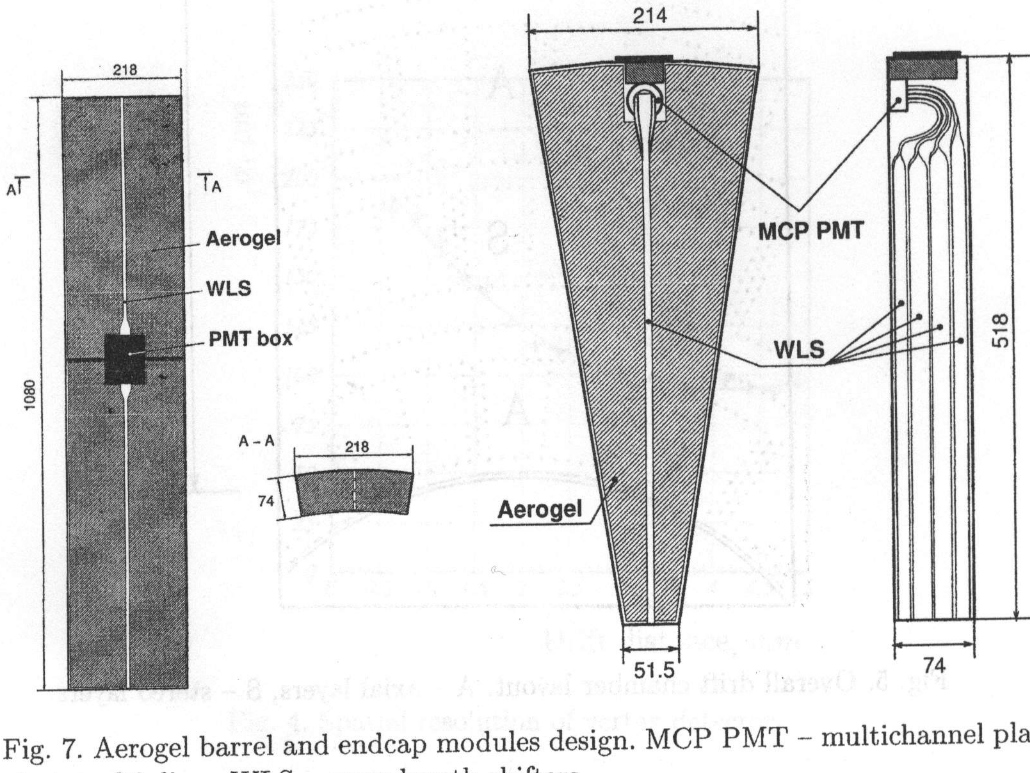

Fig. 7. Aerogel barrel and endcap modules design. MCP PMT – multichannel plate photomultipliers, WLS – wave length shifters.

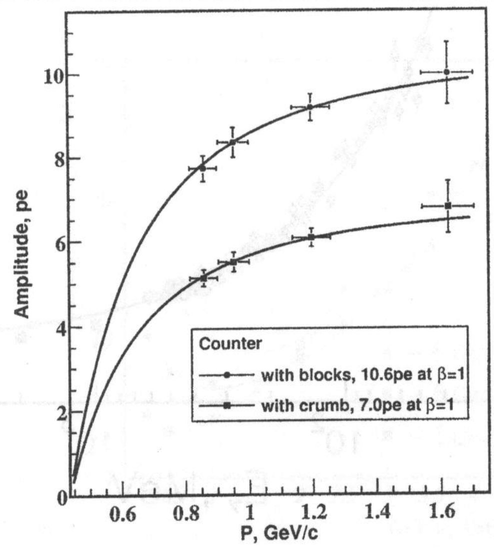

Fig. 8. The number of photoelectrons in aerogel end-cap counter versus pion momentum.

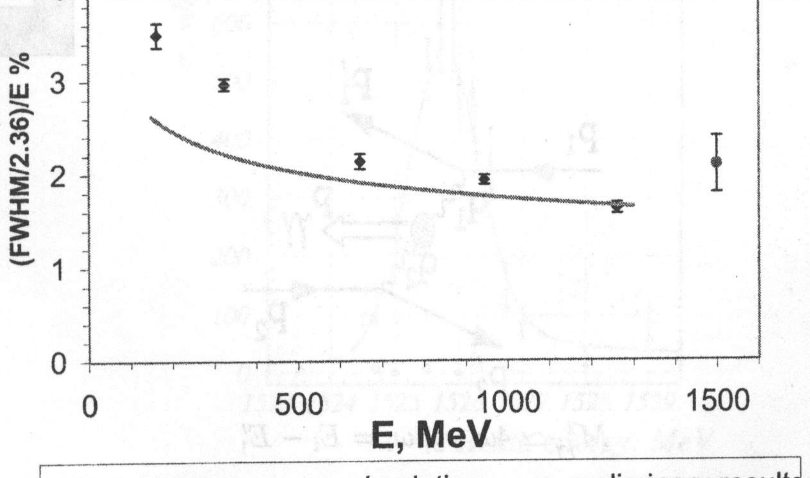

Fig. 9. Endcap calorimeter energy resolution. Preliminary results are obtained by process $e^+e^- \to e^+e^-$ at $2E = 3.1\ GeV$.

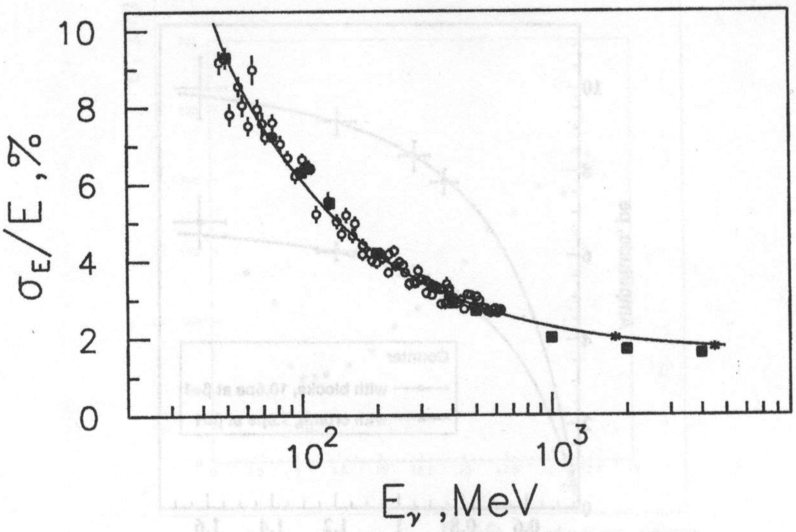

Fig. 10. Energy resolution of LKr calorimeter.

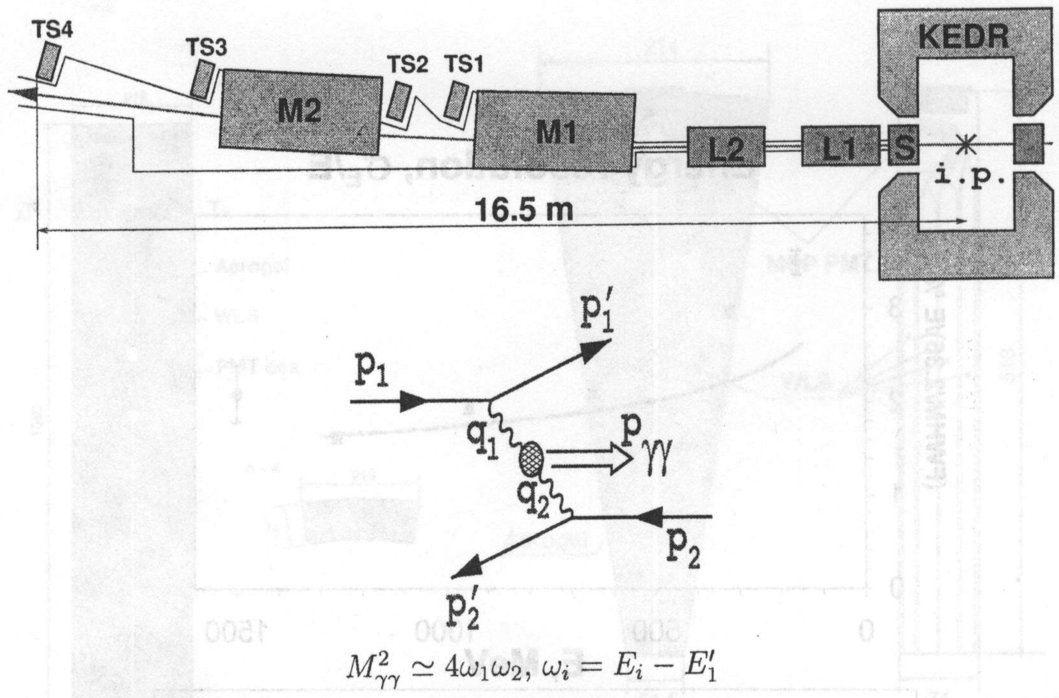

Fig. 11. Tagging system for high accuracy measurements of scattered electron and positron energies in $\gamma\gamma$-processes. S – compensating solenoid, $L1, L2$ – lenses, $M1, M2$ – bending magnets, $TS1 \div TS4$ – detection modules.

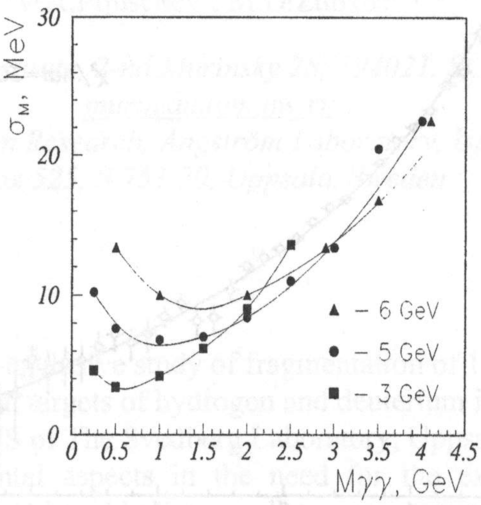

Fig. 12. Tagging system invariant mass resolution (simulations) for different c. m. energies $2E = 3, 5, 6$ *GeV*.

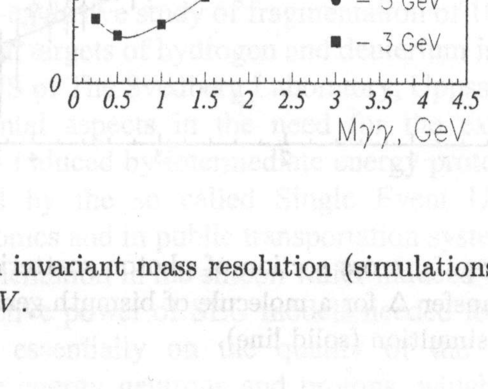

Fig. 13. Result of scans of J/Ψ-meson region with KEDR detector. • – scan with luminosity, ∘ – scan with separated beams (background measurement).

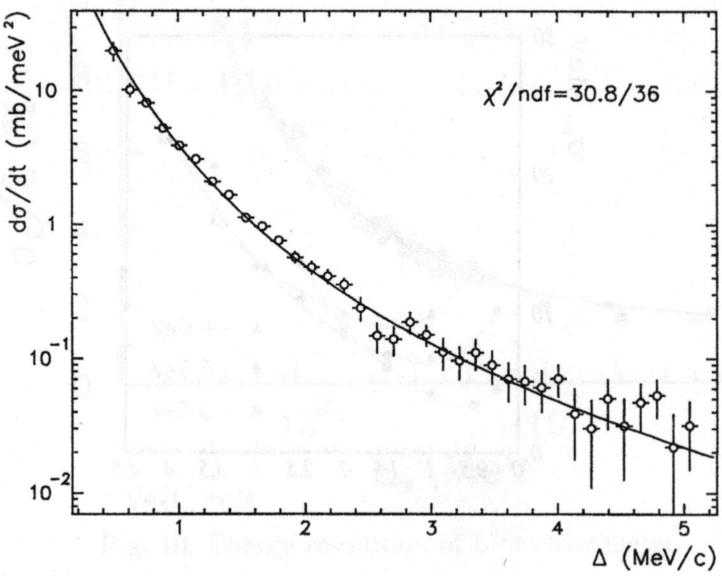

Fig. 14. The differential cross section of photon scattering $d\sigma/dt$ as a function of the momentum transfer Δ for a molecule of bismuth germanate. The experimental data (circles) and simultion (solid line).

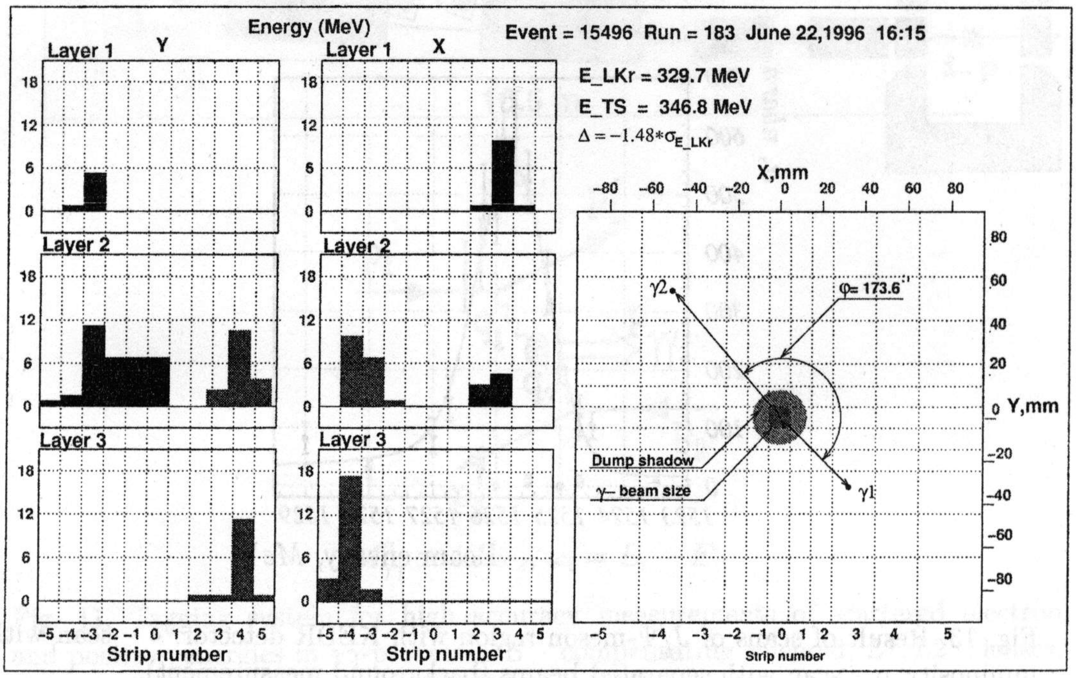

Fig. 15. Example of a photon splitting event.