



# Electromagnetic calorimeters of the CMD-3 detector

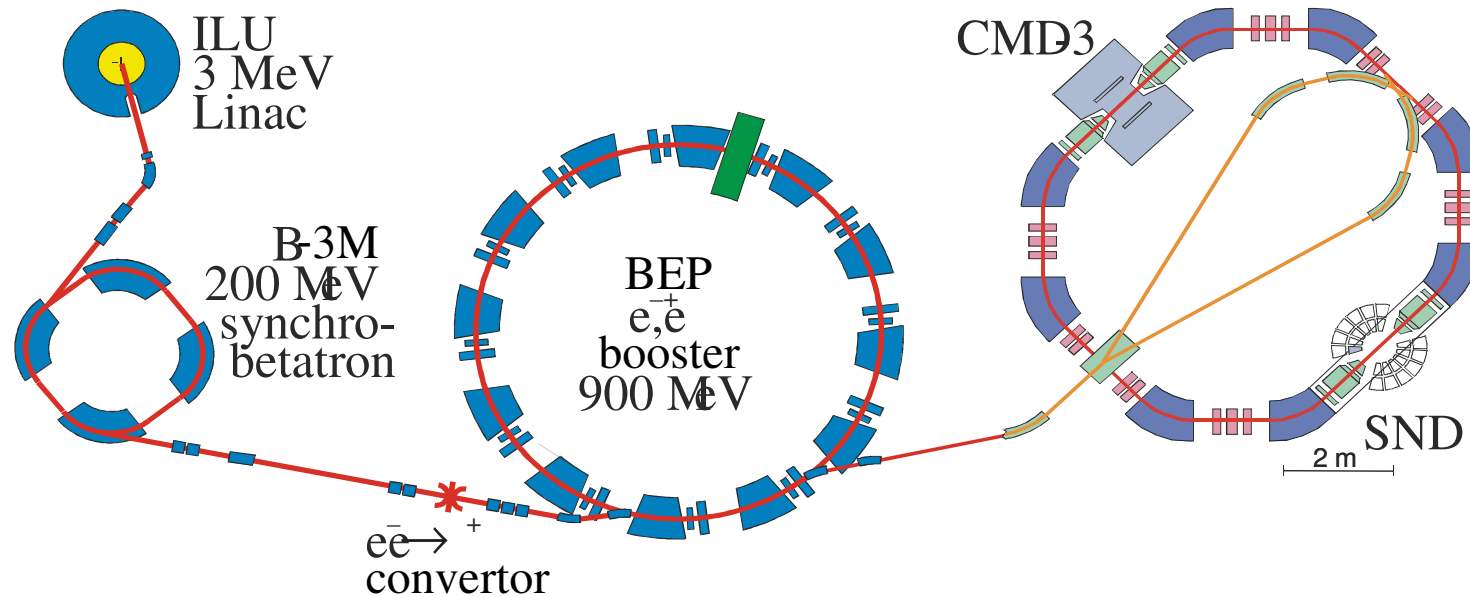
Budker Institute of Nuclear Physics  
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Outline:

- VEPP-2000 and CMD-3
- Barrel calorimeter ( LXe + CsI)
- Endcap calorimeter ( BGO )
- First results

# VEPP-2000

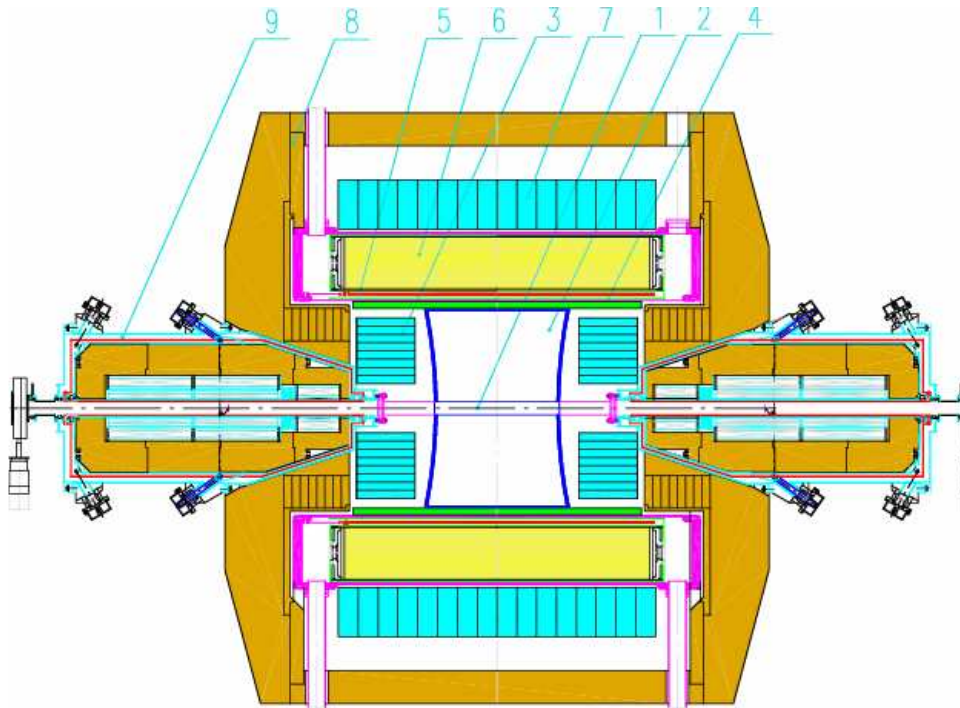
Budker Institute of Nuclear Physics, Novosibirsk, Russia



$$2E = 0.3 - 2 \text{ GeV}, L = 10^{32} \text{ cm}^{-2}\text{s}^{-1}$$

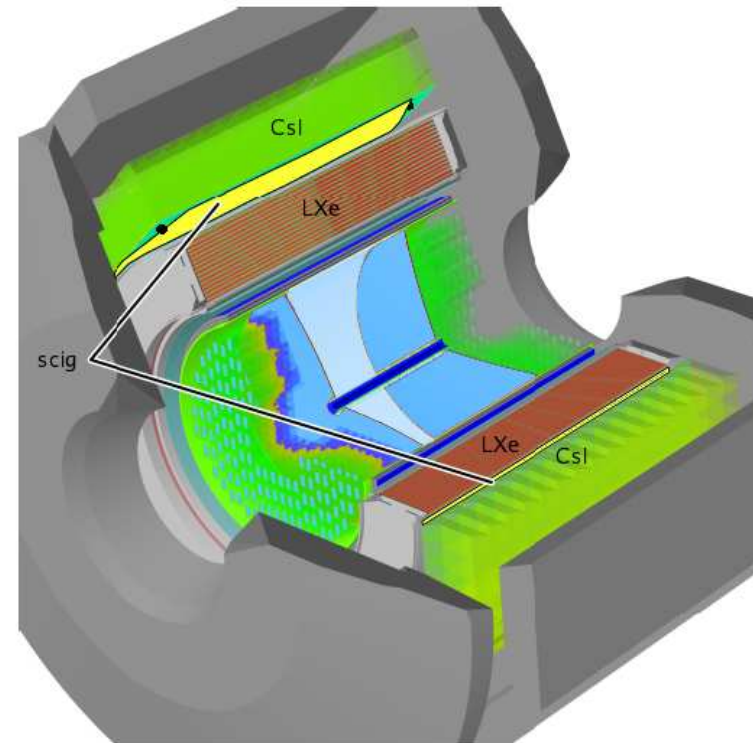
- Measurement of the  $e^+ e^- \rightarrow \text{hadrons}$  cross section in the energy range up to 2 GeV (improved determination of  $R(s)$ )
- Measurement of parameters of vector mesons  $\rho, \omega, \phi, \rho', \rho'', \omega', \omega''$
- Check of the CVC (comparison with hadronic spectral functions from  $\tau$  decays)

# CMD-3 detector



- 1 – Vacuum pipe,
- 2 – Drift chamber,
- 3 – BGO endcap calorimeter,
- 4 – Z – chamber,
- 5 – Superconducting solenoid,
- 6 – LXe barrel calorimeter,
- 7 – CsI barrel calorimeter,
- 8 – Yoke

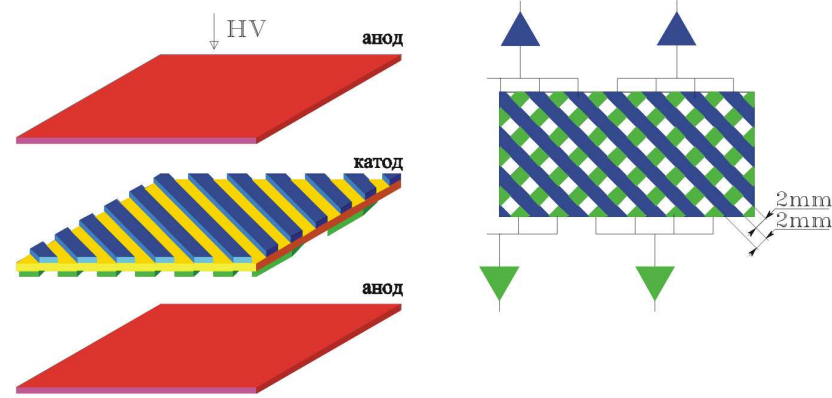
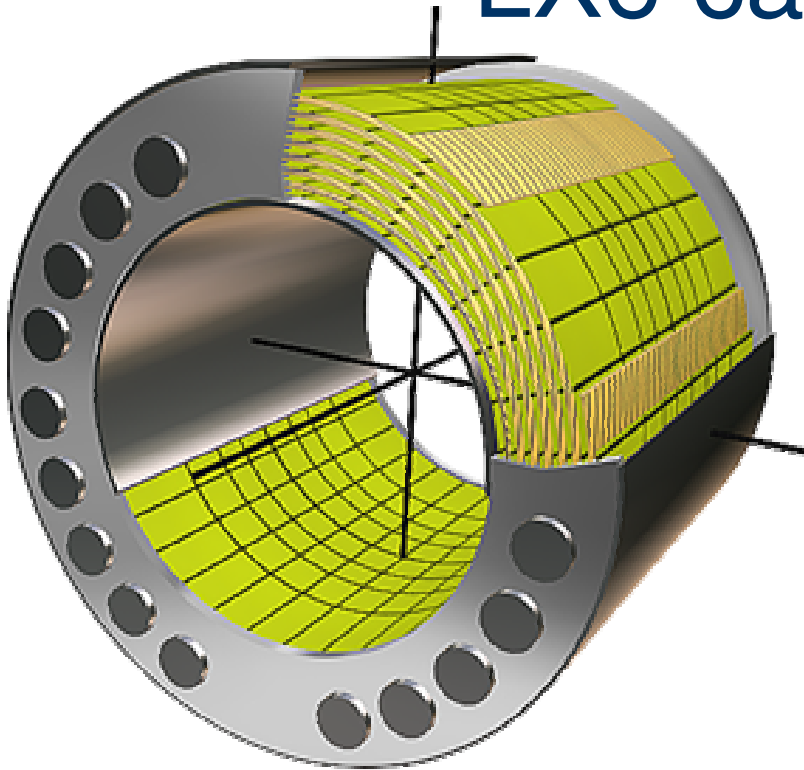
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## The main tasks for the calorimeters:

- Precise measurement of  $\gamma$  energy and coordinates in the wide energy range  $E_\gamma = 10 \text{ MeV} - 1 \text{ GeV}$
- Hadron/electron separation
- Generate signals for the neutral trigger of the detector

# LXe calorimeter



- LXe:  $\rho = 3 \text{ g/cm}^3$ ,  $w = 16 \text{ eV/pair}$
- Thickness –  $5X_0$ , Volume = 400 litre
- Purity (mean free path) – 20 mm
- Temperature=170 K, Pressure=1.2 atm.
- L. nitrogen consumption – 6 litre/hour

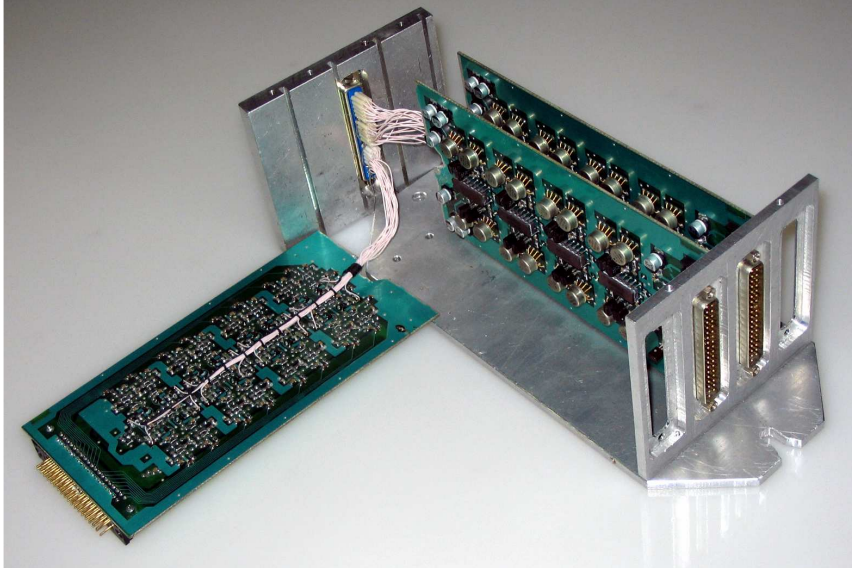
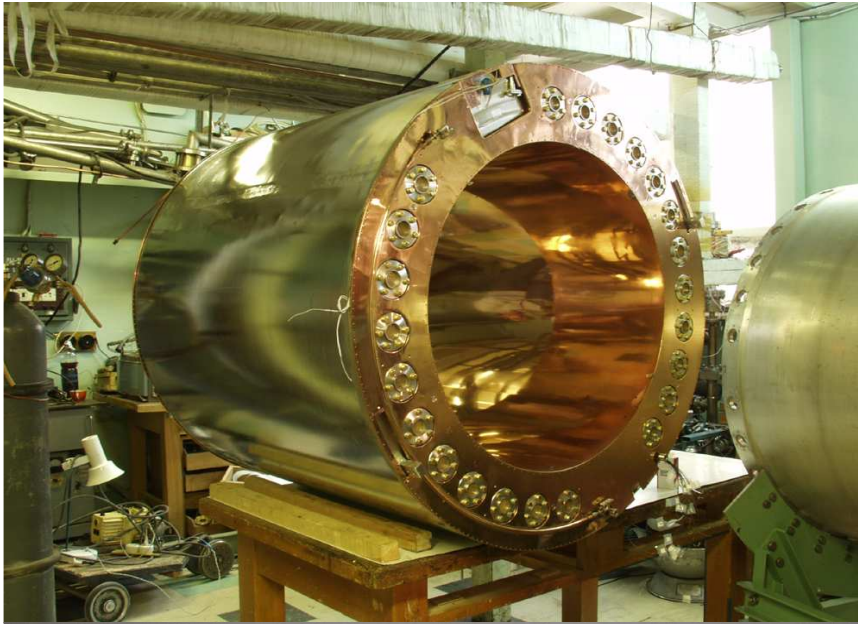
## Barrel (LXe+Csl) calorimeter

- Precise measurement of the coordinate of  $\gamma$  conversion point
- $\sigma_E/E = 4.7 - 3 \%$  ( $E_\gamma = 100 - 1000 \text{ MeV}$ )
- $\sigma_{\theta,\varphi} = 0.005$

- 15 cylindrical electrodes ( 7 – cathods, 8 - anods) with 10.2 mm gaps between them.  $R_{\text{internal}} = 369 \text{ mm}$ ,  $R_{\text{external}} = 511.8 \text{ mm}$
- 8 Anods provide energy measurement in the 264 towers. 8 - along Z, and 33 - in the R- $\varphi$  plane.
- 7 Cathods are divided into 2124 strips to measure coordinates (~300 strips per electrode )



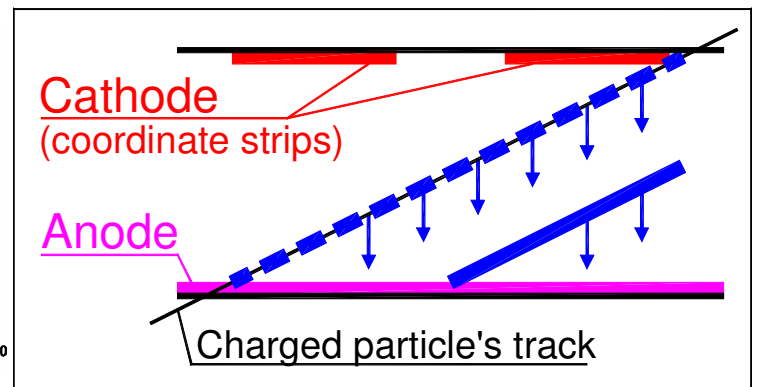
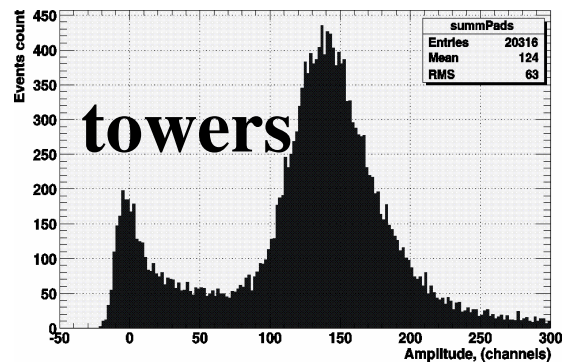
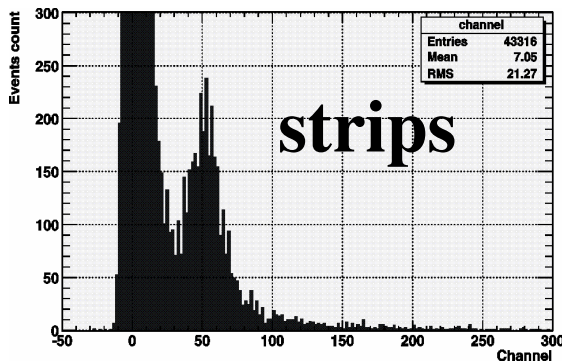
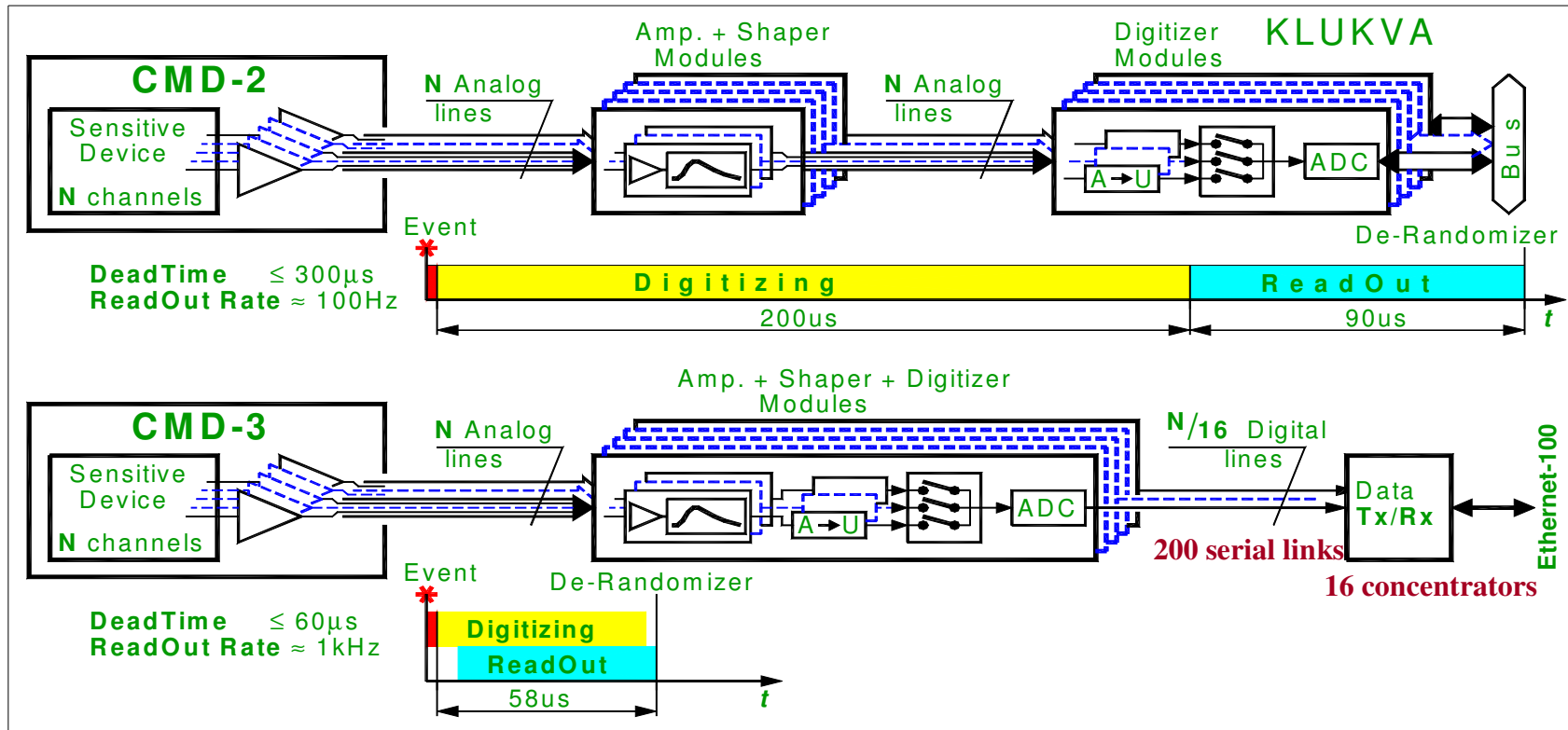
# LXe calorimeter



- **Cathods (coordinate strips):**  
typical amplitude – 36000 el., noise ~ 2200 el
- **Anods (energy towers):**  
sensitivity – 13500 el/MeV, noise ~ 3000 el  
(0.22 MeV)

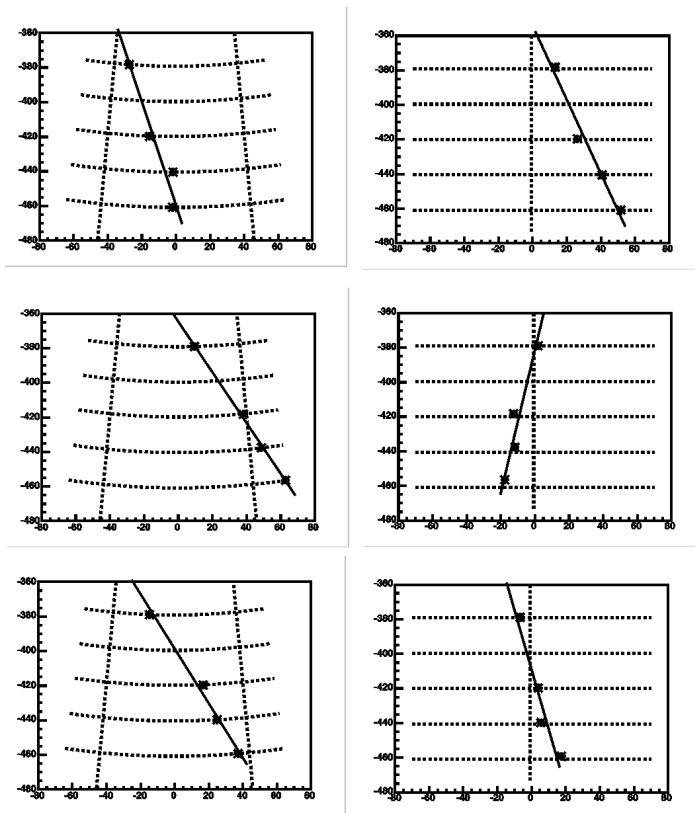
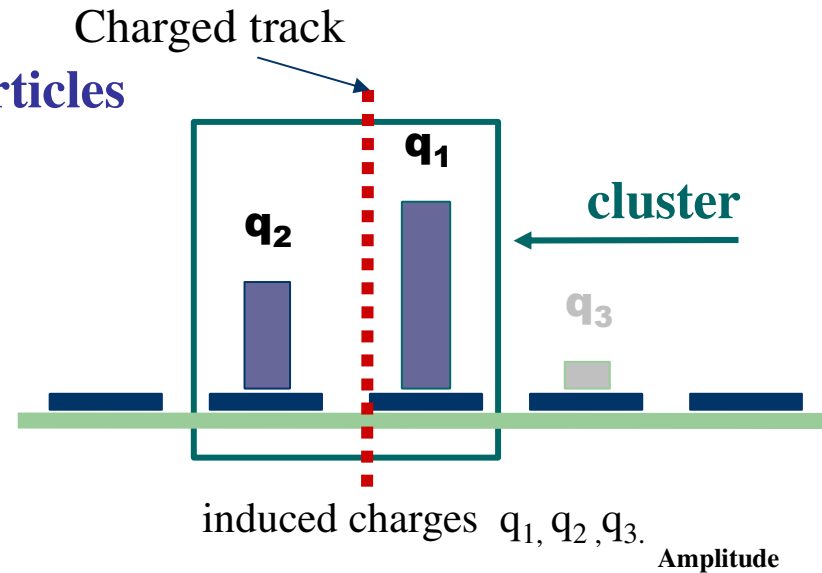
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# LXe calorimeter

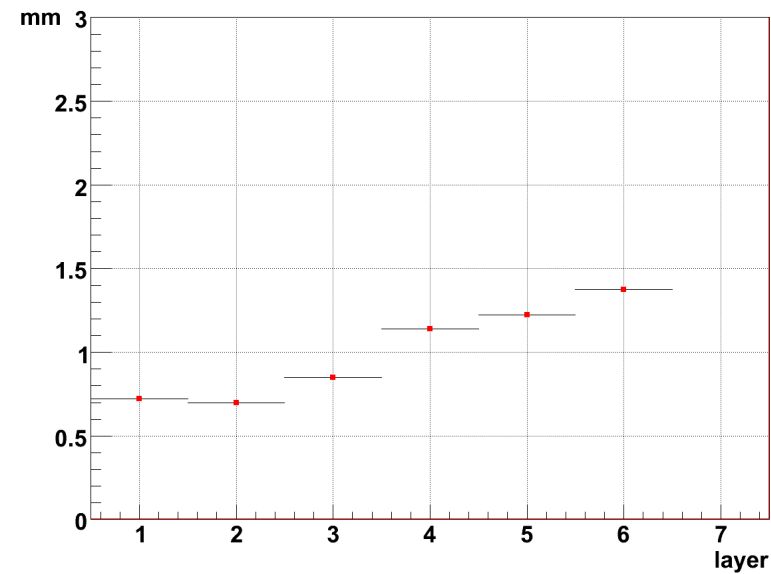


# LXe calorimeter

- Calibration with help of the cosmic particles
- Reconstruction: hit, cluster, track
- Calculation of the spatial resolution

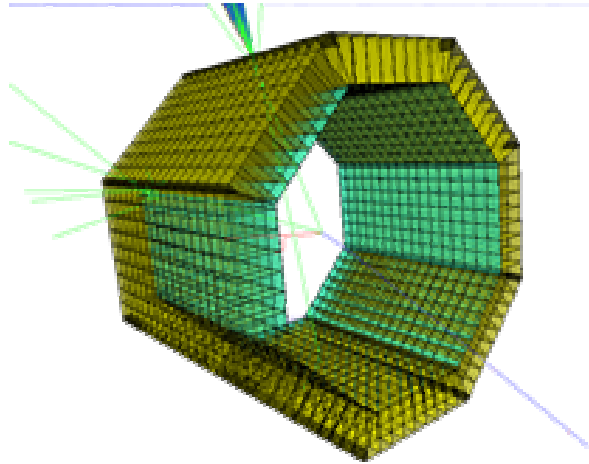


lx e dr resolution by layers



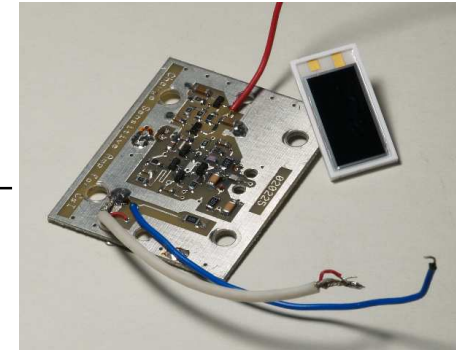
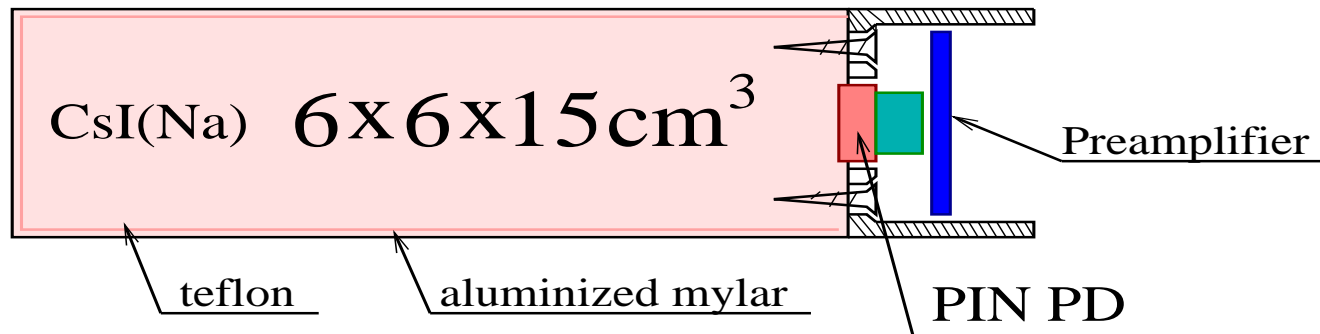


# CsI calorimeter



- Calorimeter consists of 8 octants
- Each octant is constructed from 9 modules
- Each module contains 16 counters (channels)
- Counter is made from CsI(Tl) or CsI(Na) crystal of  $6 \times 6 \times 15 \text{ cm}^3$  size,  $8X_0$

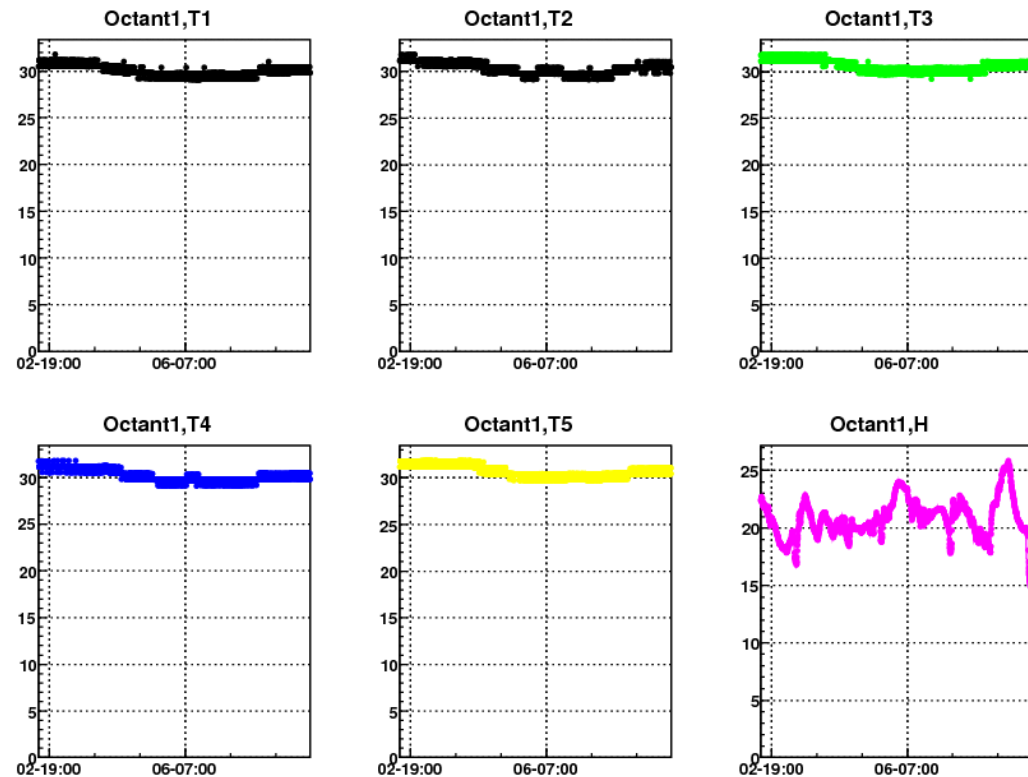
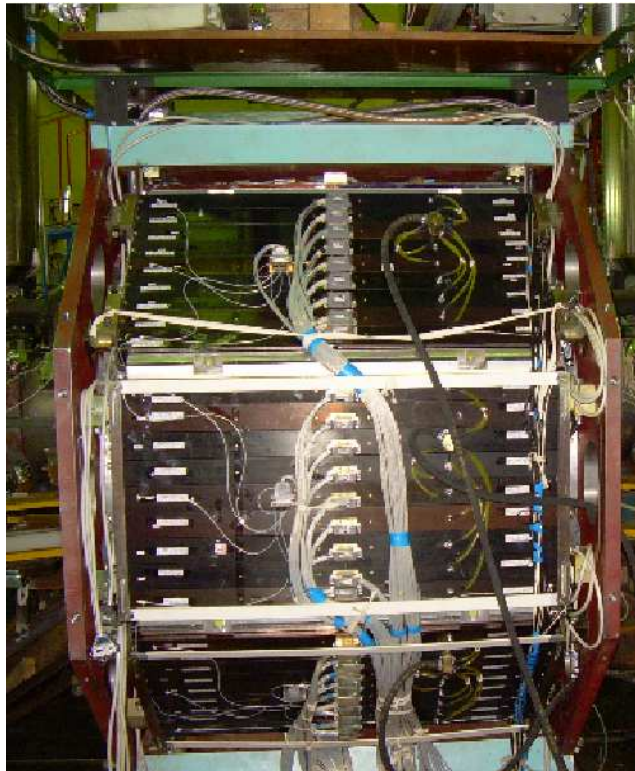
**1152 counters (total mass of the crystals is 2.8 tons )**



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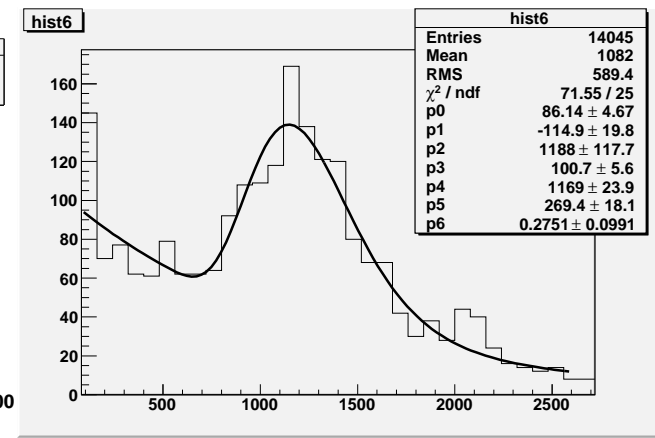
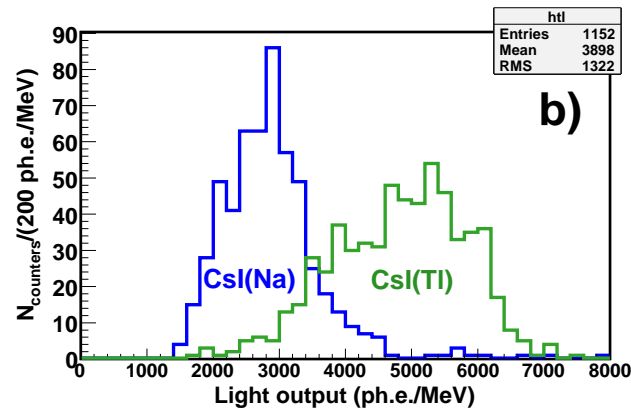
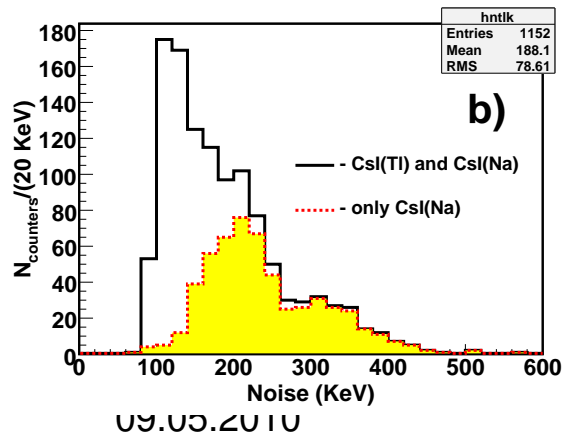
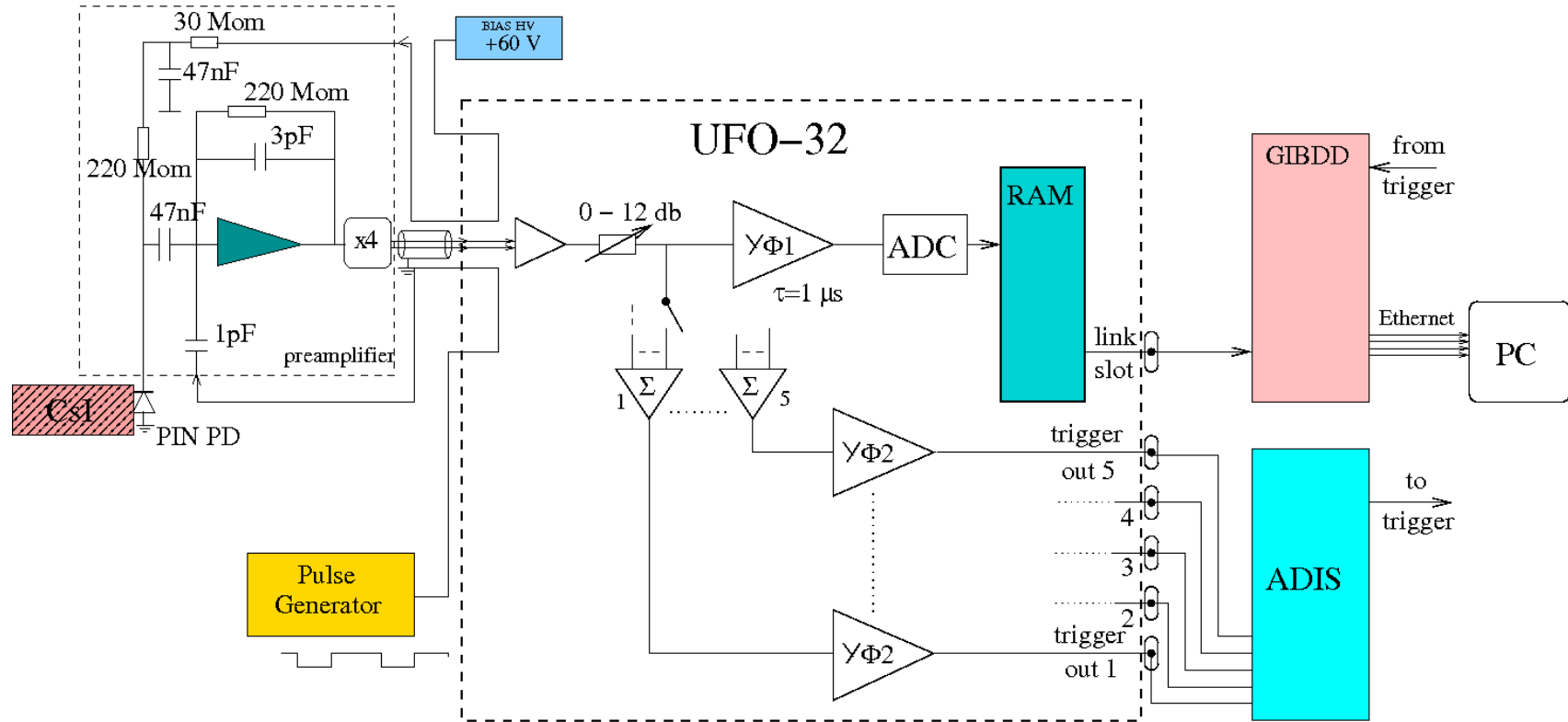
# Csl calorimeter



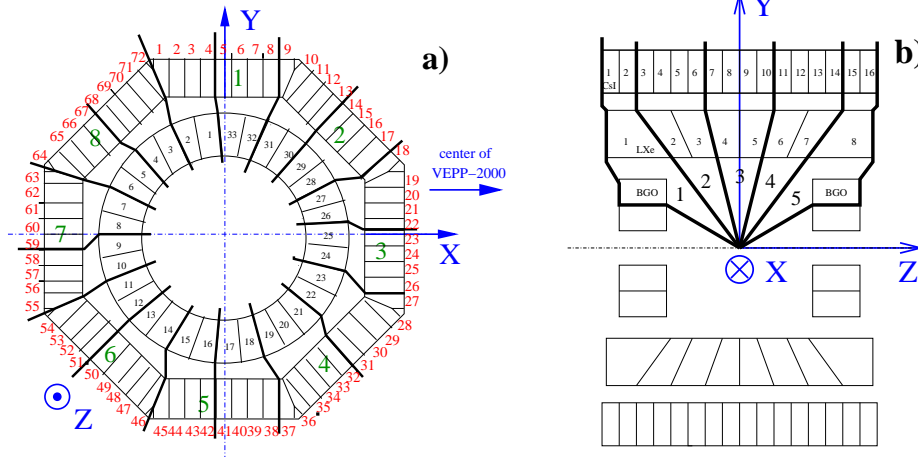
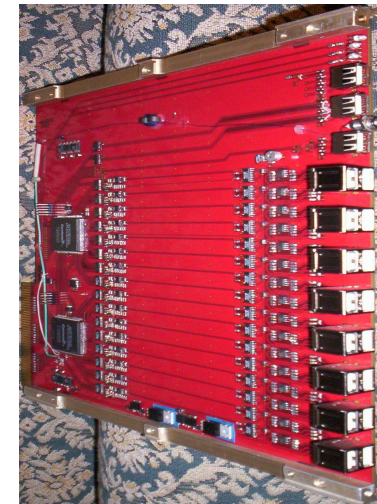
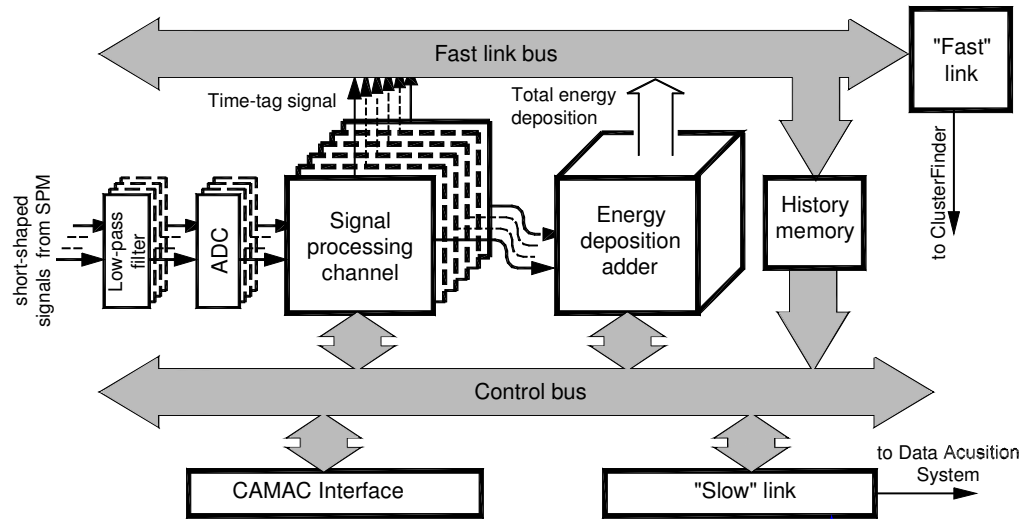
- Signals from all counters are processed by 39 32ch-Amplifier-Shaper-Digitizer boards
- From the boards the data come to the online PC-farm through the special interface board
- Finally information is recorded to the raw-data file

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# CsI calorimeter

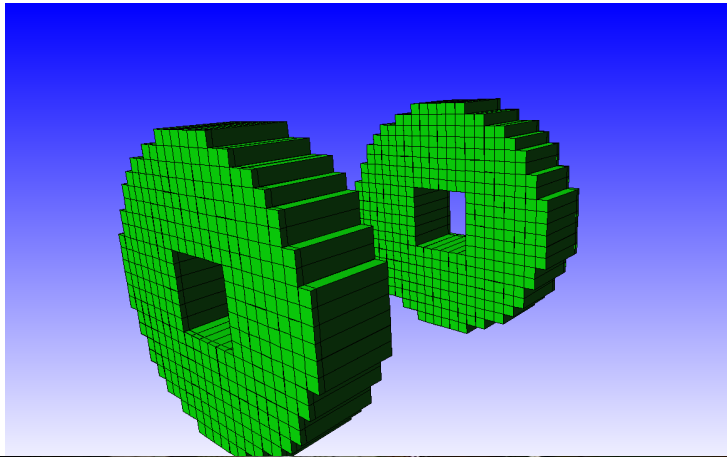


# CsI calorimeter

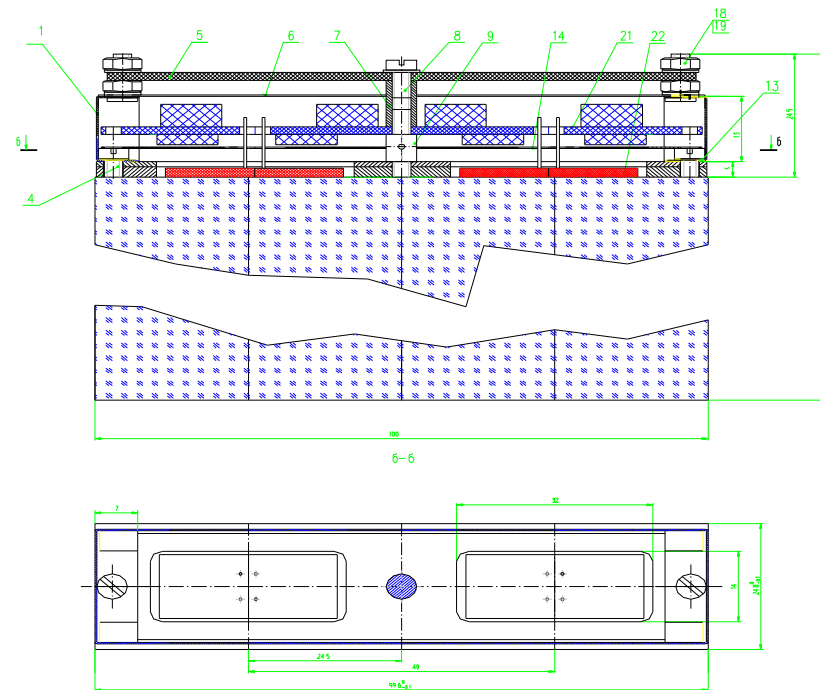


- LXe: 80 trigger cells
- CsI: 80 trigger cells
- BGO: 48 trigger cells

# BGO calorimeter



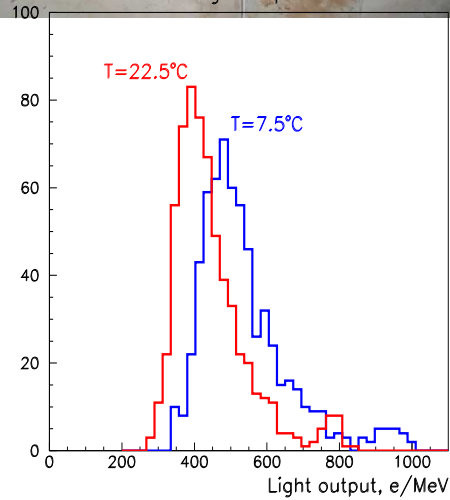
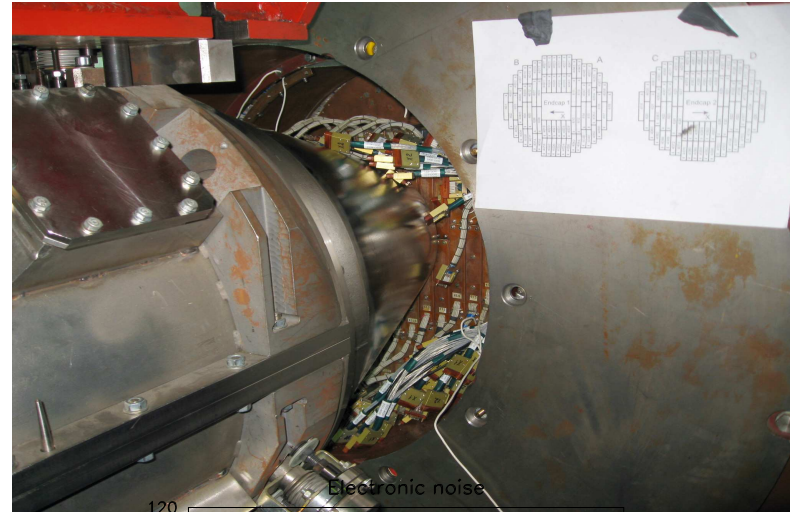
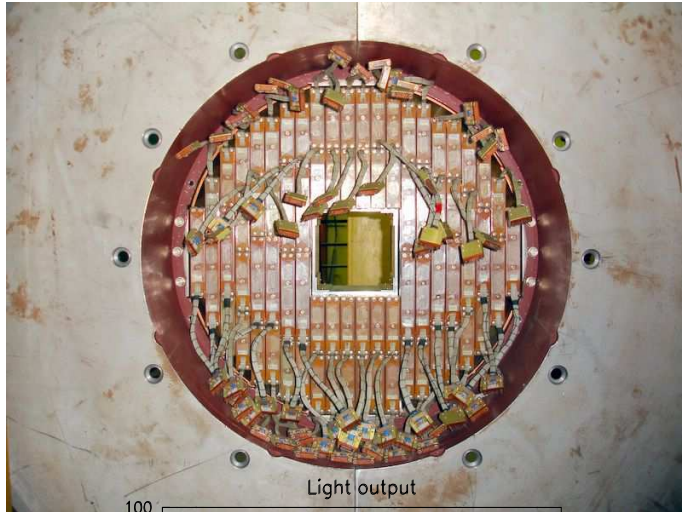
- Calorimeter contains 680 counters (total mass of the crystals is 450 kg) and covers  $0.3 \cdot 4\pi$  sterad.
- Counter is made from BGO crystal of  $25 \times 25 \times 150 \text{ mm}^3$  size,  $13.5X_0$
- $\sigma_E/E = 8 - 4 \%$  ( $E_\gamma = 100 - 1000 \text{ MeV}$ )
- $\sigma_\theta = 0.03 - 0.02 \text{ rad}$



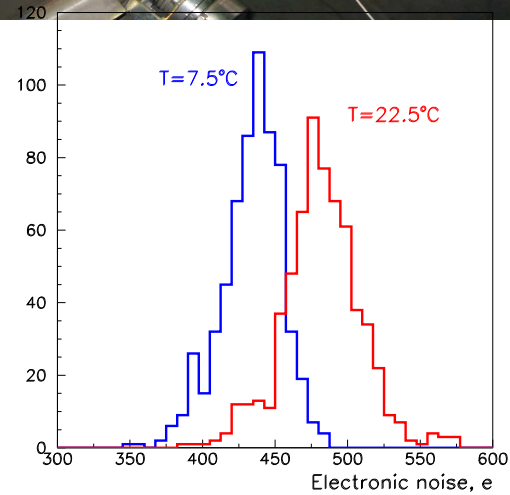
**Sensitivity – 500 el./MeV,  $\sigma_{el} \sim 500 \text{ el. (1 MeV)}$**



# BGO calorimeter



Light output increase ~ 20 %



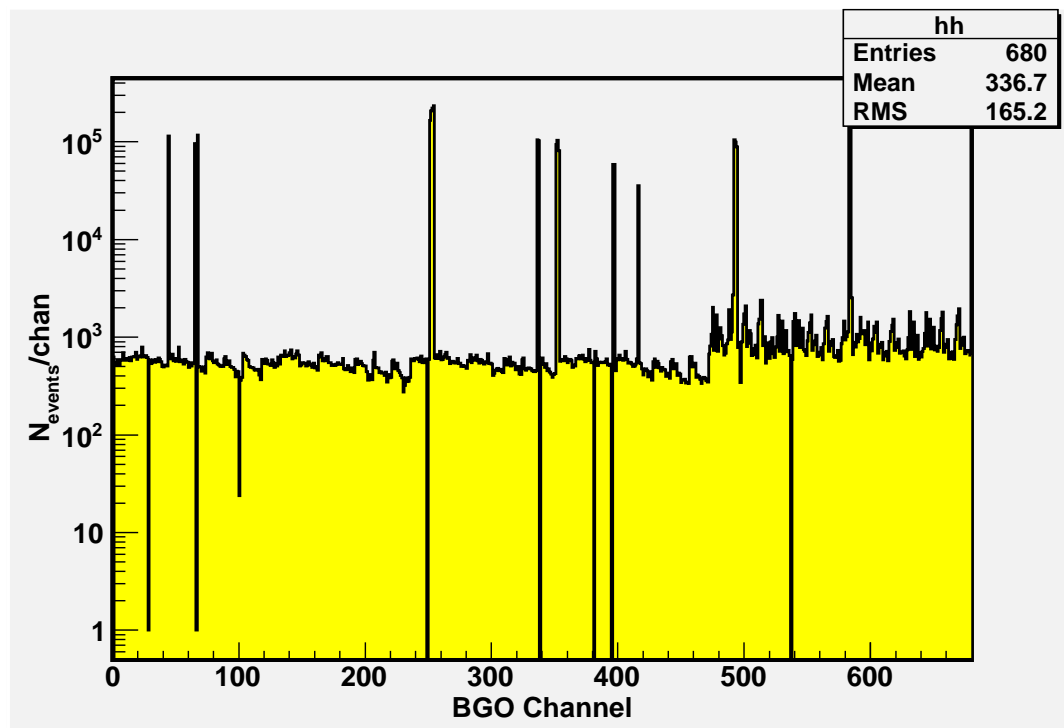
Electronic noise decrease ~ 10 %

- **Special cooling system is used**
- **Operation of the calorimeter at  $T = 18 \text{ }^\circ\text{C}$**

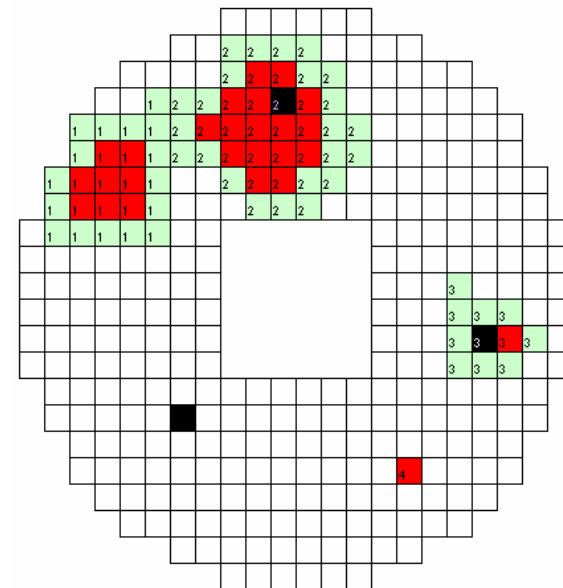
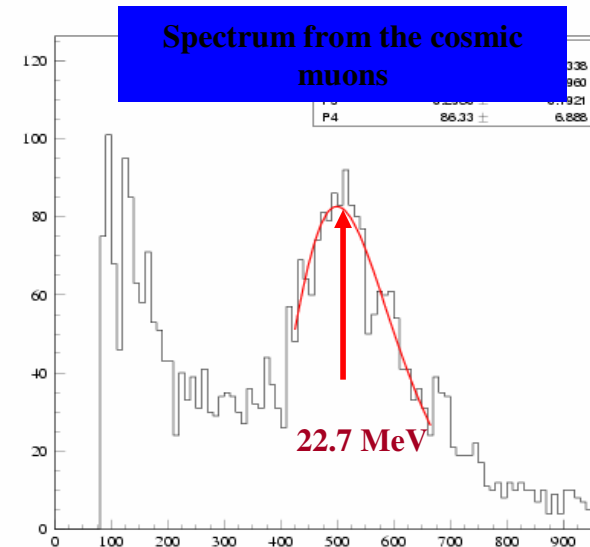
# BGO calorimeter

- Calibration with help of the cosmic muons
- Reconstruction of the clusters
- Calibration using Bhabha events

## BGO channels occupancy

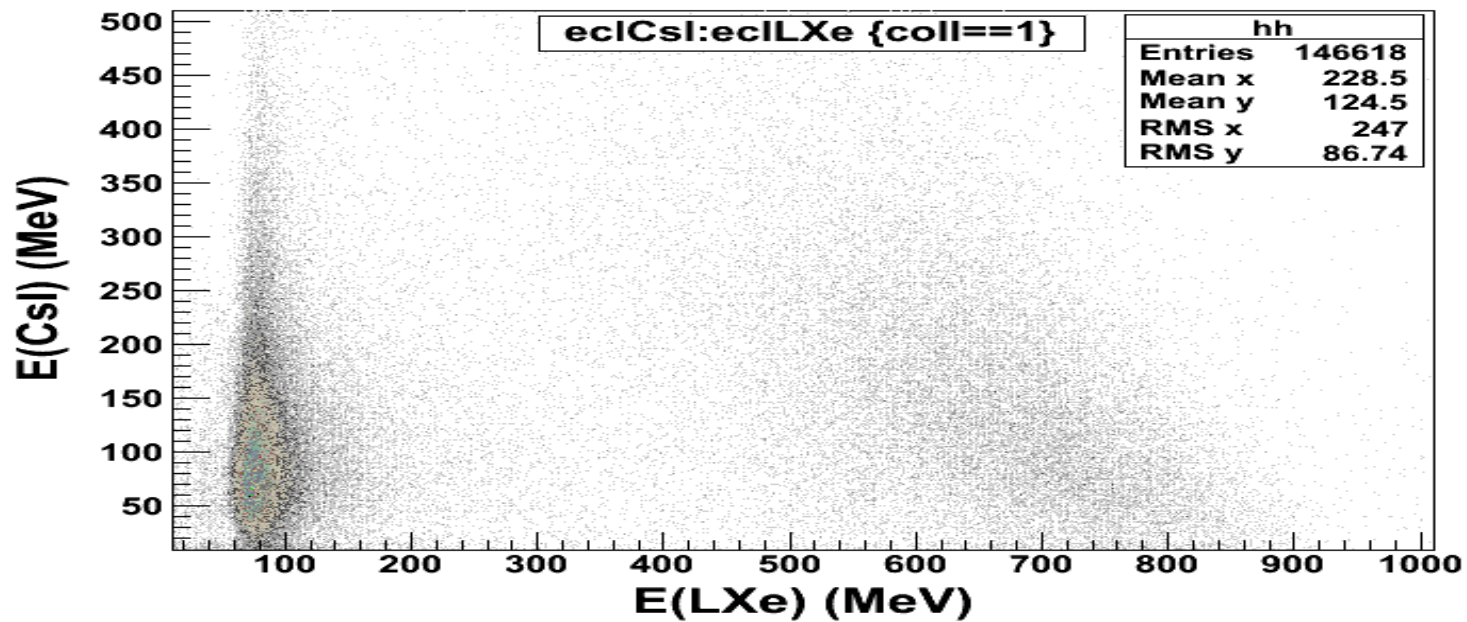
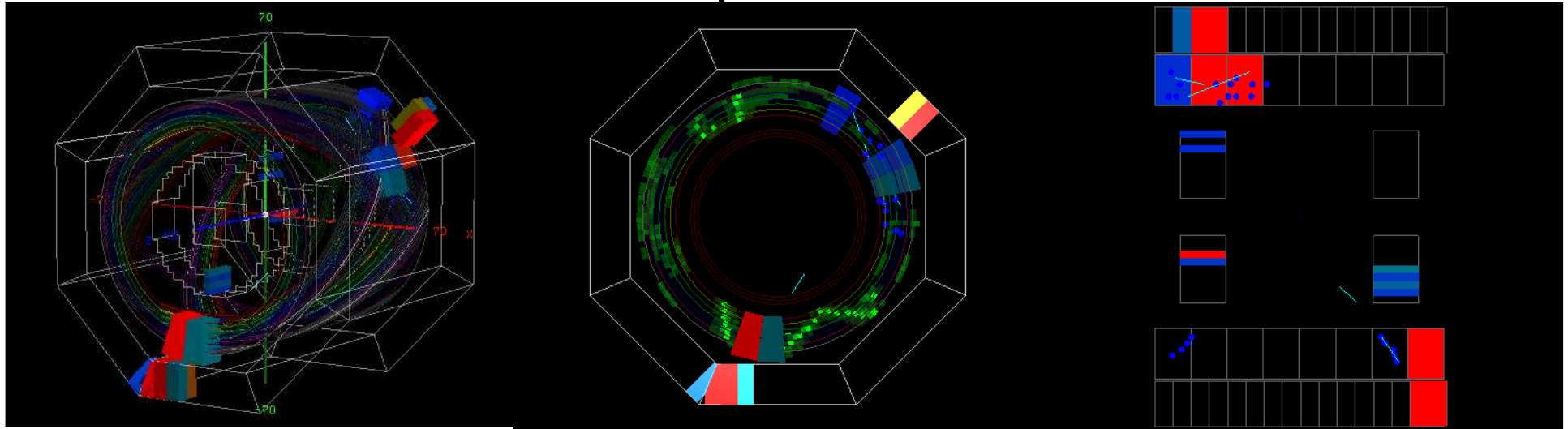


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# CMD-3 experimental event



- $E_\gamma = 350$  MeV: LXe – 80%, CsI – 20% (MC)
- $E_\gamma = 950$  MeV: LXe – 70%, CsI – 30% (MC)

# Conclusion

- Calorimeters are installed in the detector
- Their electronics is integrated in the DAQ system
- Experimental runs have been started
- Monitoring of all channels is doing with calibration signal from the generator
- Energy calibration is doing with help of the cosmic muons
- Work on the procedure of energy calibration with Bhabha events is in progress
- Neutral trigger system is tested and will be included soon
- Works on the global reconstruction of the event are in progress



# Backup slides

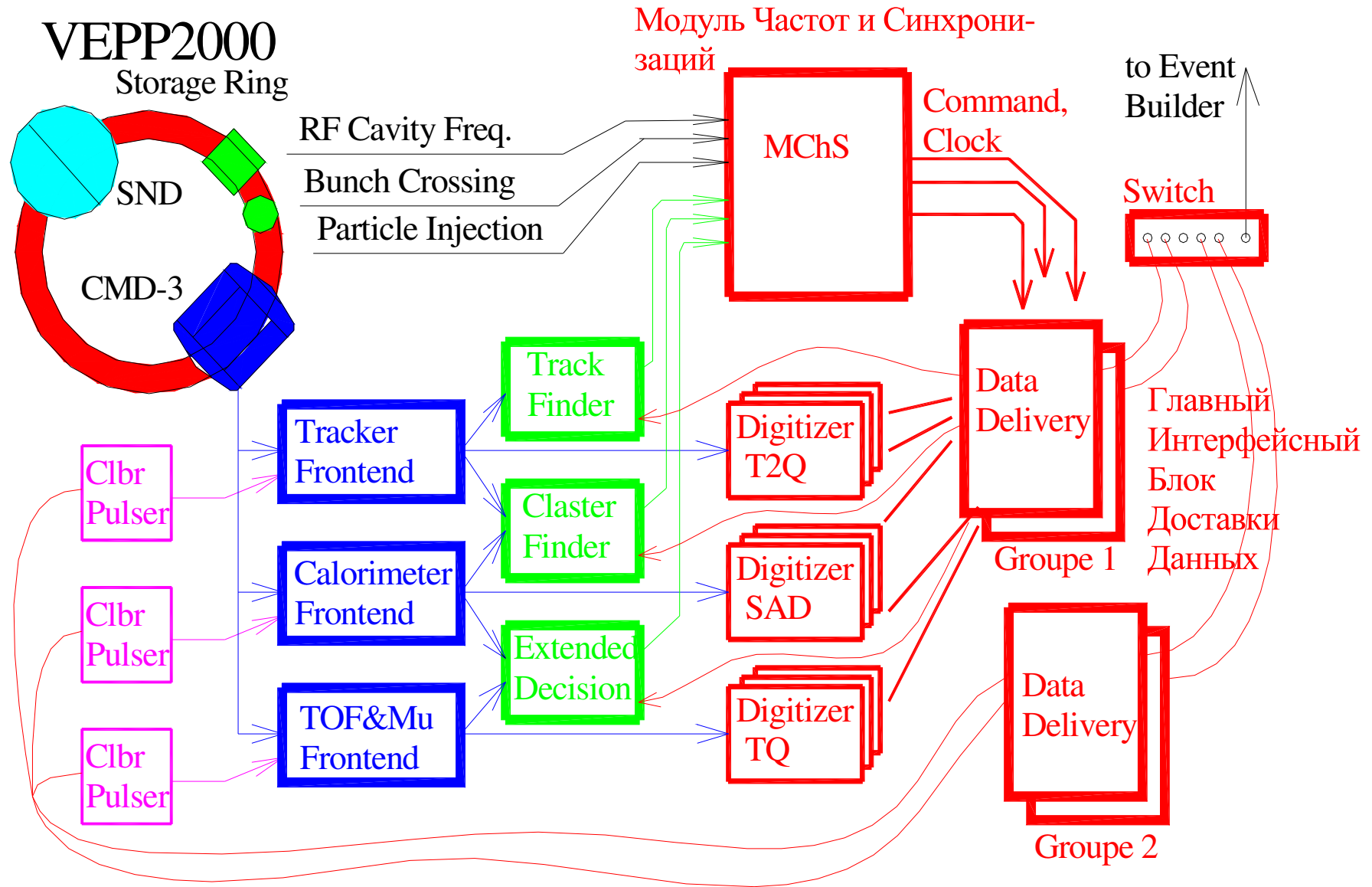


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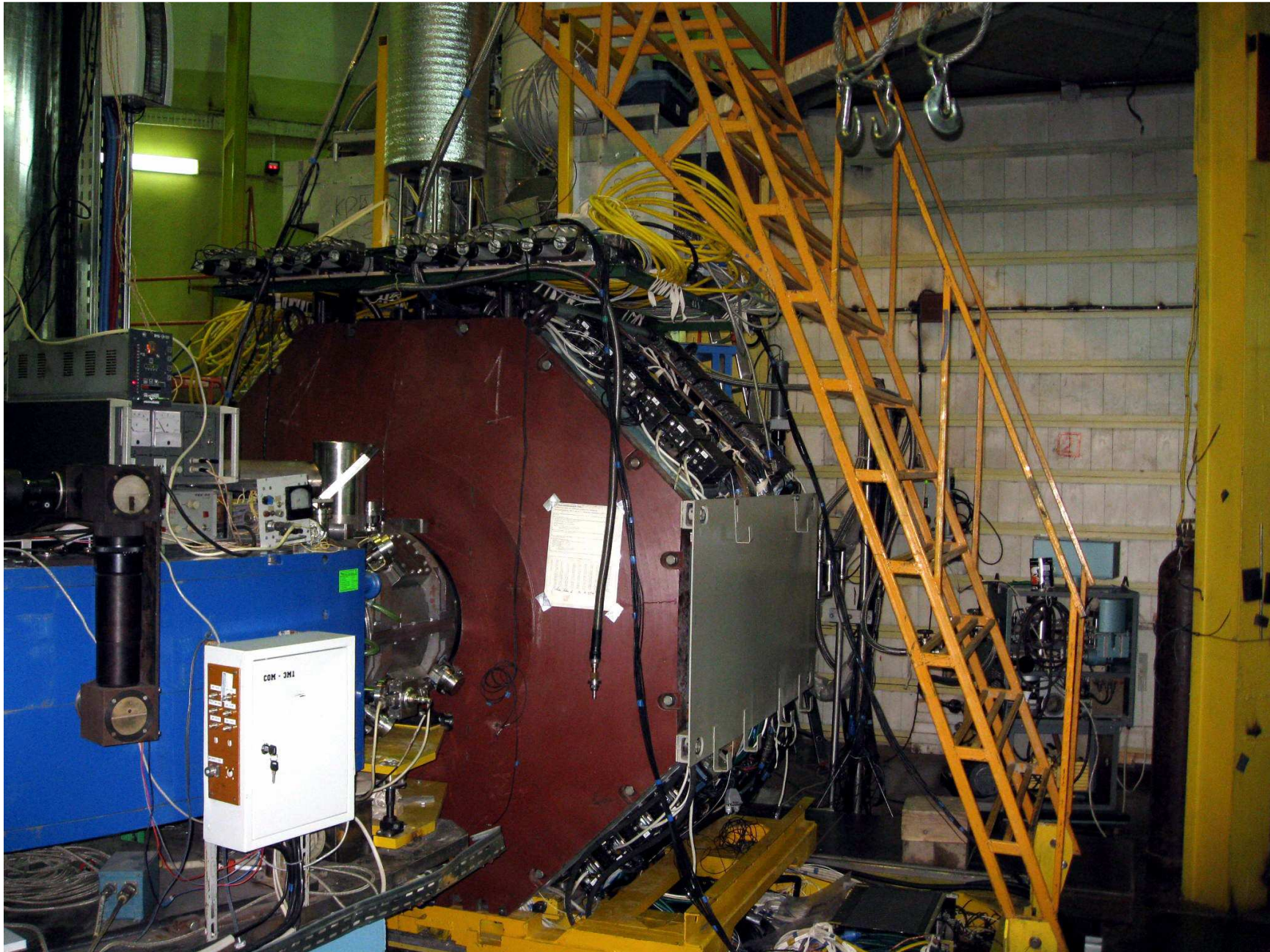
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Source of error	2pi $\sqrt{s} < 1 \text{ GeV}$	2pi $\sqrt{s} > 1.0 \text{ GeV}$	4pi $\sqrt{s} > 1.1 \text{ GeV}$
Event separation	0.2%	0.2%	1% (cuts)
Fiducial volume	0.2%	0.2%	2% (model)
Energy calibration	0.1% (0.3%)	0.1% (1.0%)	1%
Efficiency correction	0.2% (0)	0.2% (0)	1% (tr+bg)
Pion losses (decay, NI)	0.2% (0.1%)	0.2% (0.1%)	
Other			0.3% (свєт.)
Radiative corrections	0.15%	0.15%	1%
Total	0.4%	0.4%	2.5%
Total (no dep.)	0.5%	1.0%	
Total (high eff.)	0.3%	0.3%	

# DAQ





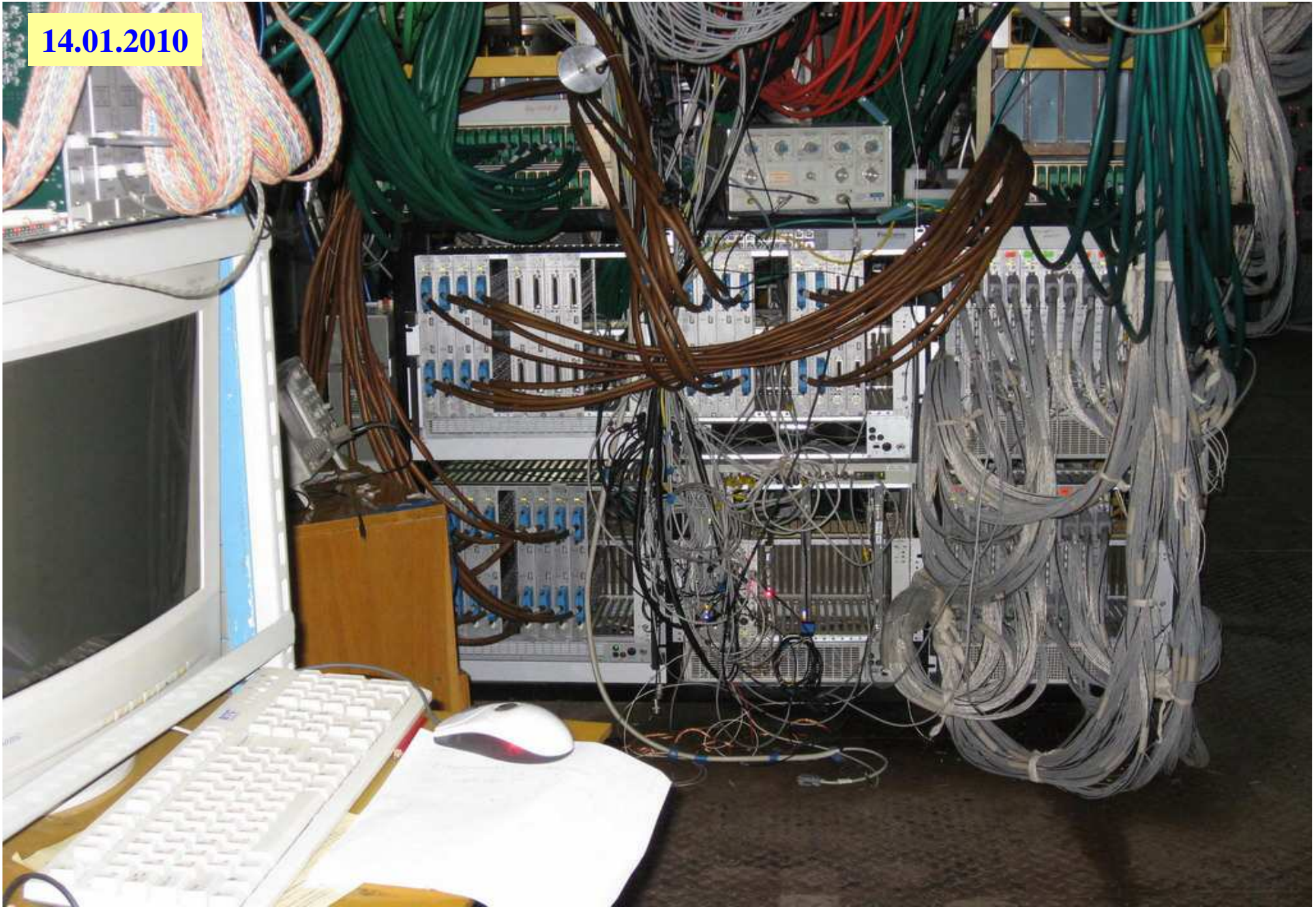


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