

Registration system for the experiment BEST

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Main parts of the counting system for BEST

1. Passive shield.
2. Proportional counters.
3. Anticoincidence system (NaI(Tl) detector).
4. Charge-sensitive preamplifiers.
5. System acquisition electronics.
6. On-line software.

The passive shield of the counting system for BEST

Pad: Quartz sand.

Basis: $200 \times 200 \times 200$ mm³ cubes of low-background concrete.

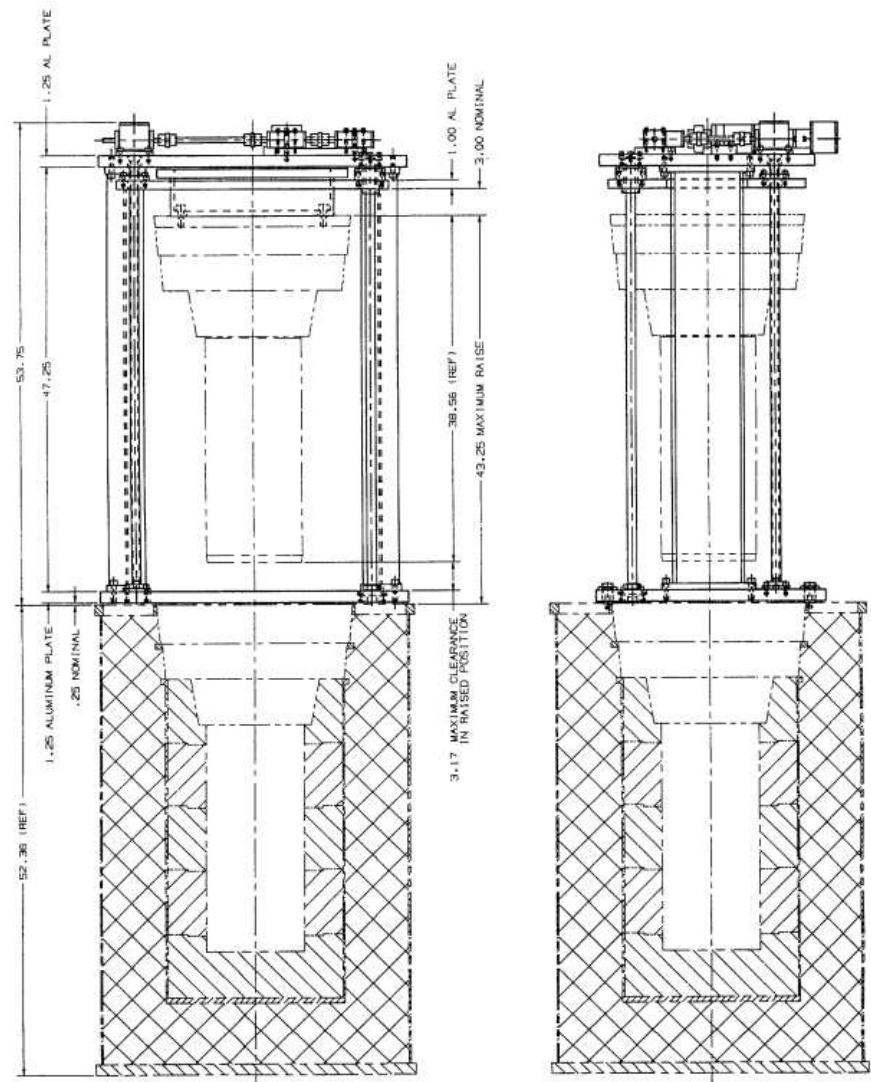
Internal layer: 107.5 mm (around), 130 mm (down and up) of copper.

Intermediate layer: 20 mm (down and around) of steel.

External layer: 300 mm (down and around) of lead ($\simeq 1000$ bricks).

Upper cover: 100+100 mm of steel.

Total mass: about 20 t.



The counting system for BEST: YCN counters

Cathode length: $\simeq 50$ mm

Wall thickness: 150–200 μm

Cathode diameter: 4 mm (int.)

Cathode: $\simeq 1$ μm (pirographite)

Anode thickness: 11 μm (tungsten)

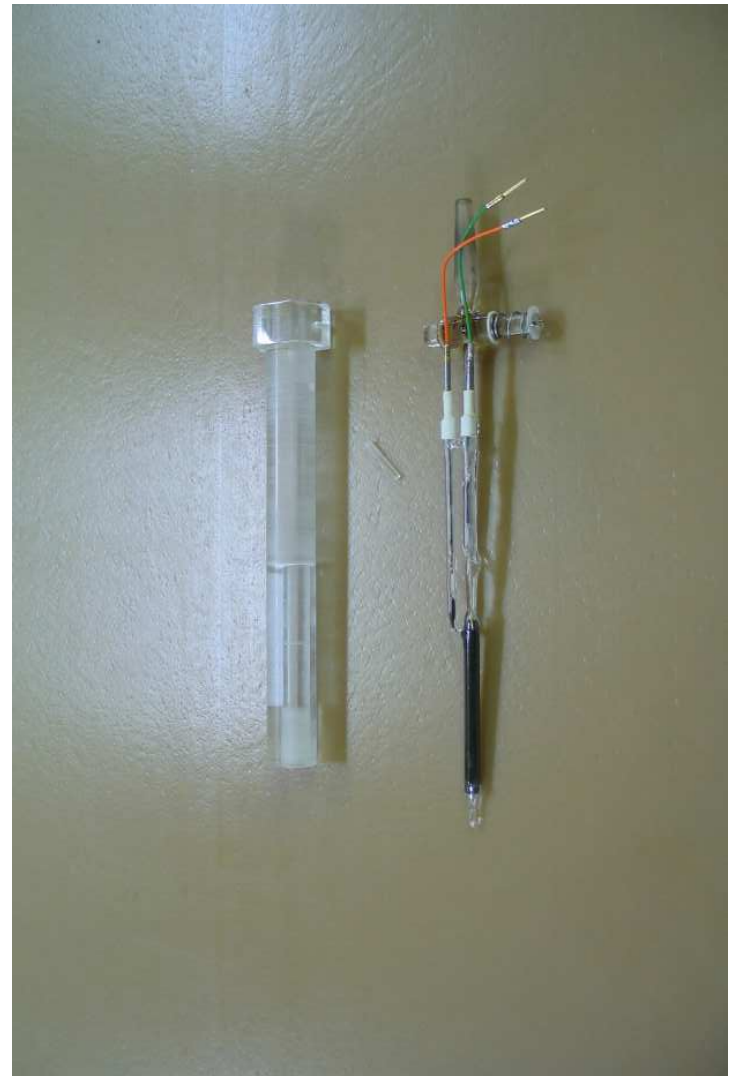
Gas mixture: (10–20)% $\text{GeH}_4 + \text{Xe}$

Gas pressure: 620–640 mm

High Voltage: $-(1100-1300)$ V

Gain: 10^3-10^4

Energy resolution (5.9 keV): 19–23%



The measured data of the YCN counters

| Counter YC* | N-32 | N-41 | N-42 | N-43 | N-46 | N-113 | N-a9 | T-8 |
|-------------------------|------|-------|-------|-------|-------|-------|-------|-------|
| $\bar{R}, \%$ (5.9 keV) | | 19.96 | 20.54 | 20.11 | 23.20 | 20.02 | 21.14 | 20.70 |
| $\sigma_R, \%$ | | 0.34 | 0.41 | 0.75 | 0.42 | 0.64 | 1.09 | 1.25 |
| Bkg_L, d^{-1} | | 0.23 | 0.83 | 0.11 | 0.31 | 0.17 | 0.20 | |
| Bkg_K, d^{-1} | | 0.13 | 1.24 | 0.05 | 0.23 | 0.06 | 0.20 | |

Main data of NaI(Tl) detector

Made: “Amkris”, Kharkov, Ukraine

Size: $\varnothing 200 \times 200$ mm

Well: $\varnothing 100 \times 150$ mm

PMTs model: 3” ET9757QL (4 pieces.)

Body: Stainless steel

Reflector: Teflon

Windows: Quartz

Volume: 5105.1 cm^3

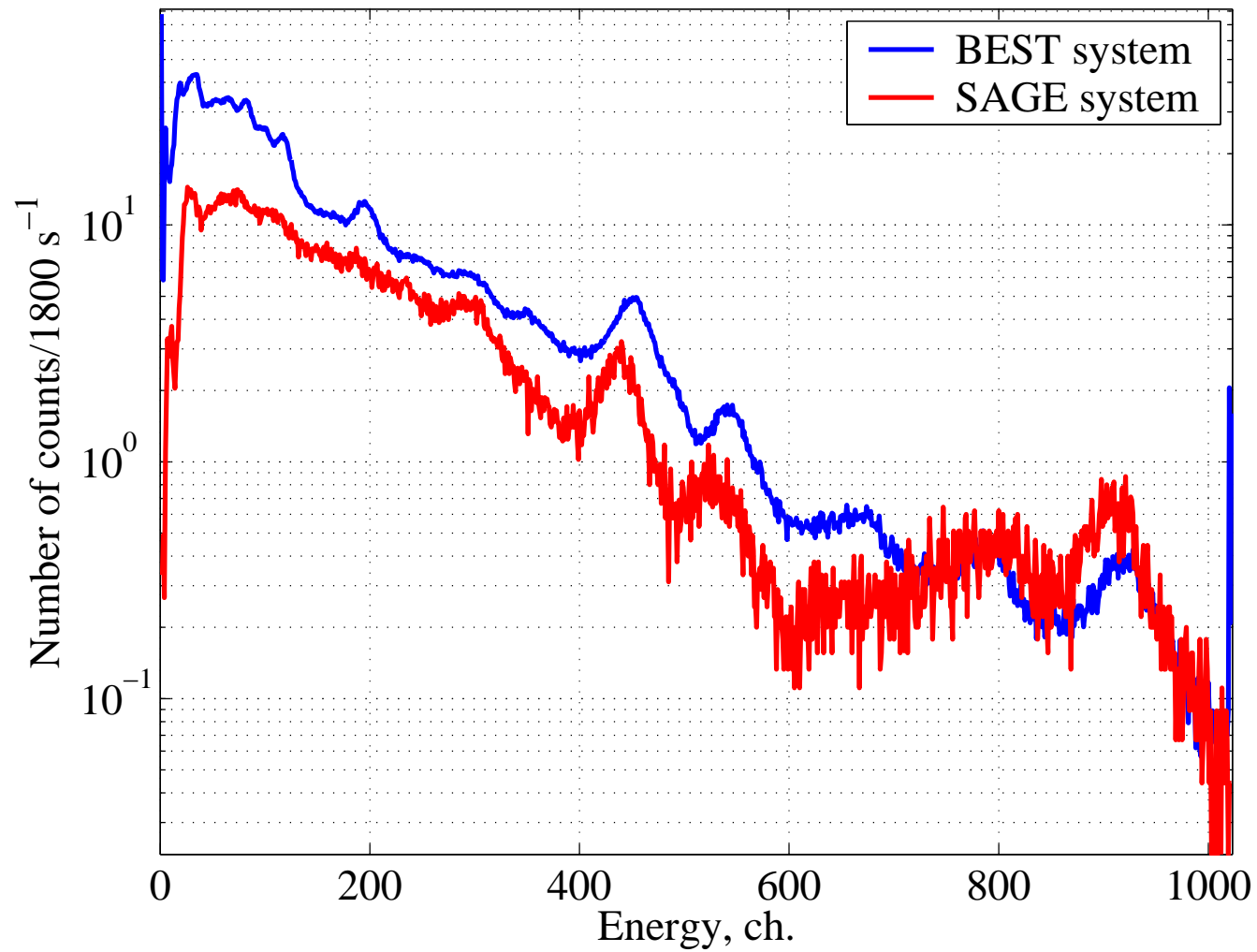
Mass: 18.74 kg

Resolution: $R \simeq 7.6\%$
($E_\gamma = 1460 \text{ keV}$)

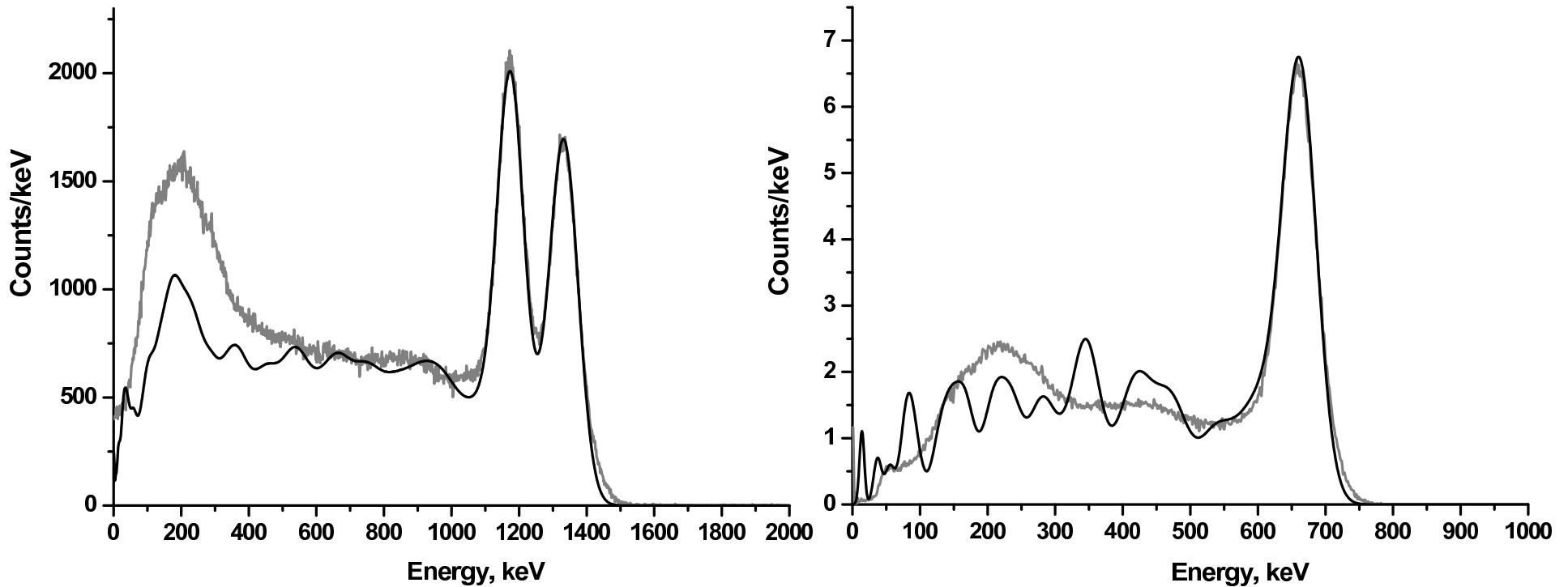
Bkg: $v_{\text{bg}} = 3.24 \pm 0.03 \text{ s}^{-1}$
($E_\gamma = 40\text{--}3500 \text{ keV}$)



The background spectra of NaI(Tl) detectors

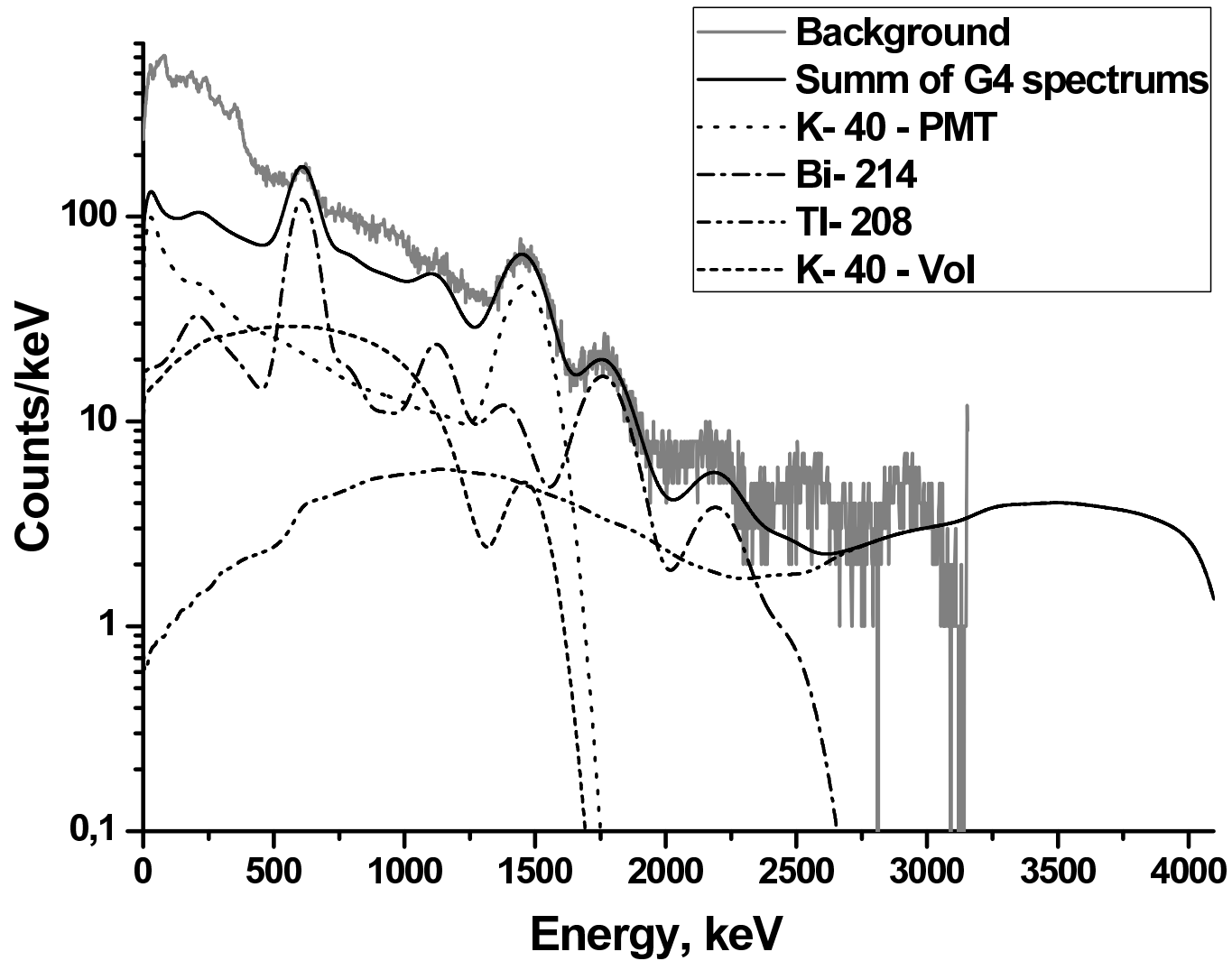


Calibration spectra of NaI(Tl) detector of the system for BEST

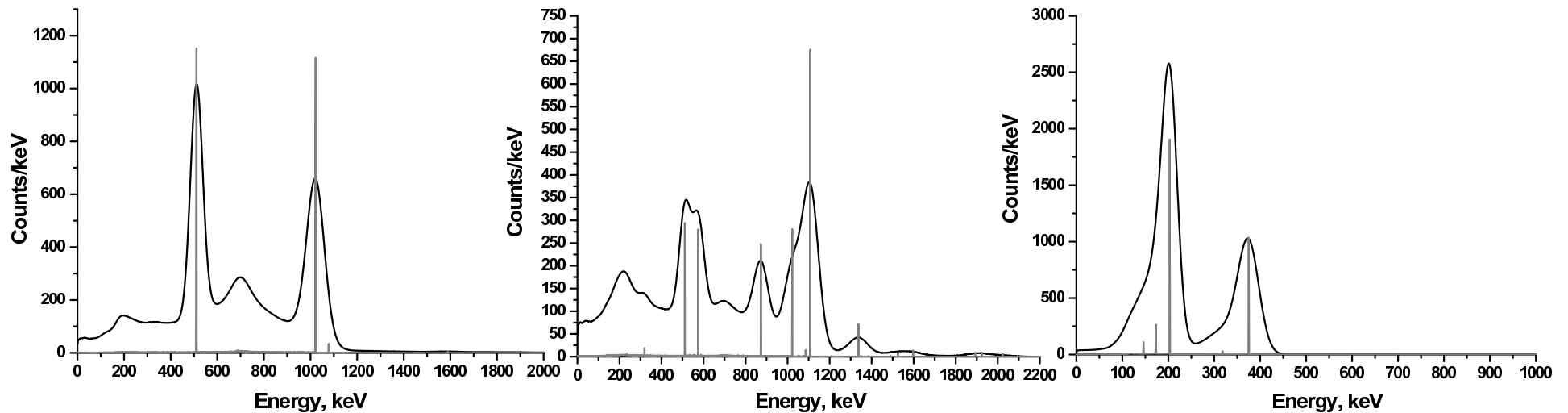


Left: ^{60}Co , right: ^{137}Cs . Grey lines — real spectra, black lines — Geant 4 model spectra.

The background of NaI(Tl) detector of the system for BEST: real spectrum and Geant 4 model



The NaI(Tl) detector: Geant 4 model response on different γ -sources in a place of proportional counter

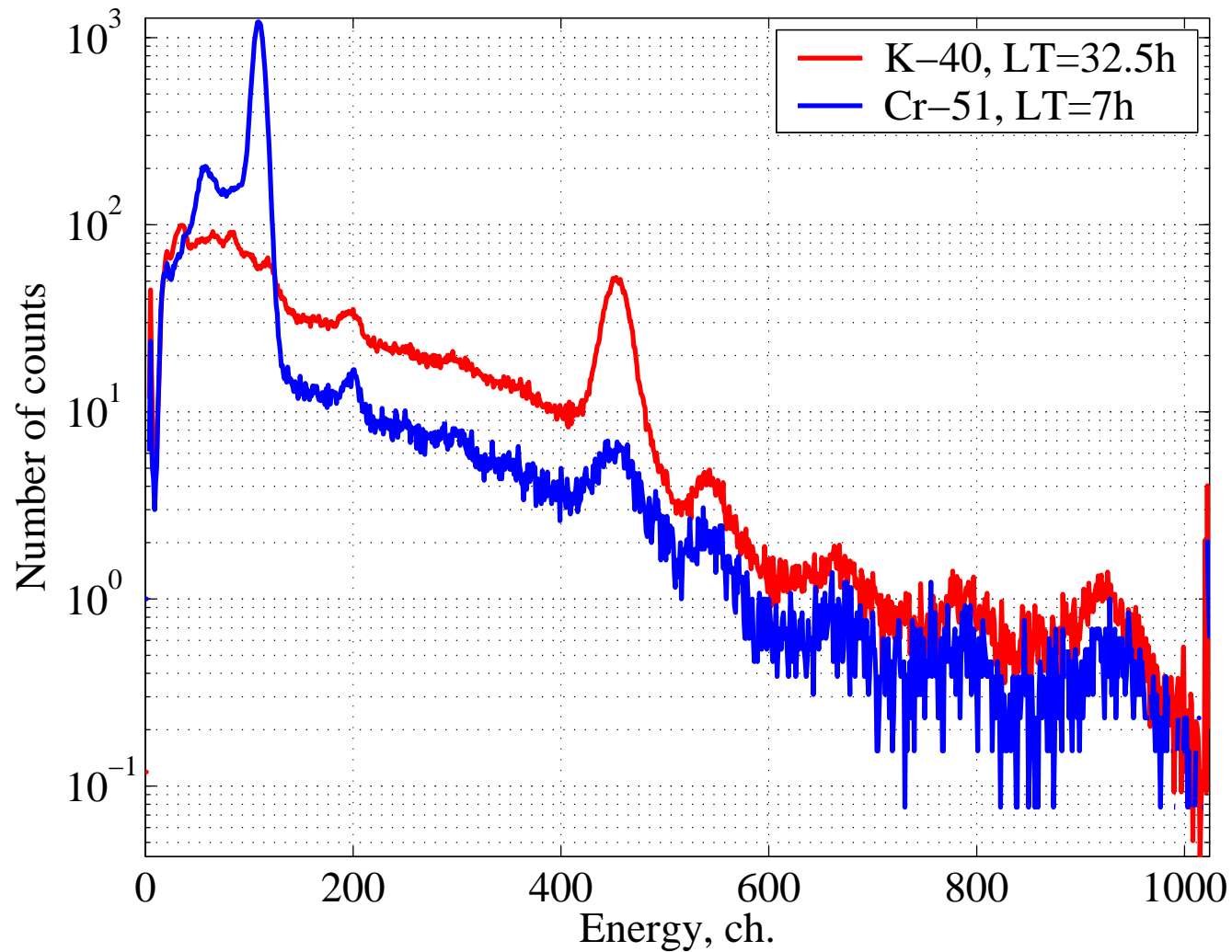


From left to right: ^{68}Ga , ^{69}Ge and ^{127}Xe . Grey lines — model response, black lines — model response with consideration of energy resolution of real detector.

Efficiencies of γ -lines registration for sources in a place of proportional counter, % (Geant 4 model)

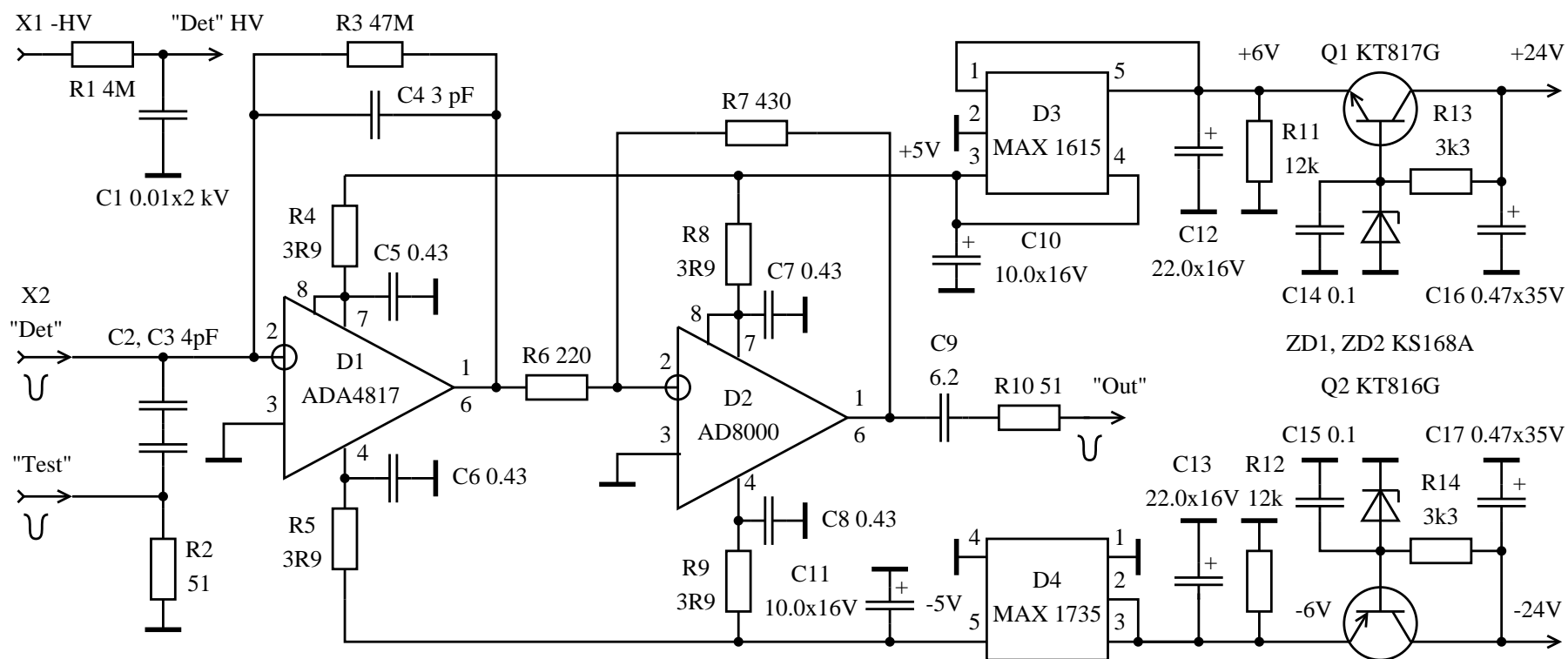
| E, keV | 145 | 172 | 203 | 375 | 511 | 574 | 872 | 1107 | 1336 | 1460 | Abs. |
|-------------------|------|------|------|------|------|------|------|------|------|------|------|
| ^{127}Xe | 43.0 | 17.2 | 46.2 | 99.5 | | | | | | | 78.7 |
| ^{69}Ge | | | | | 10.5 | 35.0 | 34.5 | 31.0 | 27.0 | | 69.5 |
| ^{68}Ga | | | | | 10.5 | | | | | | 87.5 |
| ^{40}K | | | | | | | | | | 28.0 | 77.0 |

The NaI(Tl) detector: real response on different γ -sources in a place of proportional counter

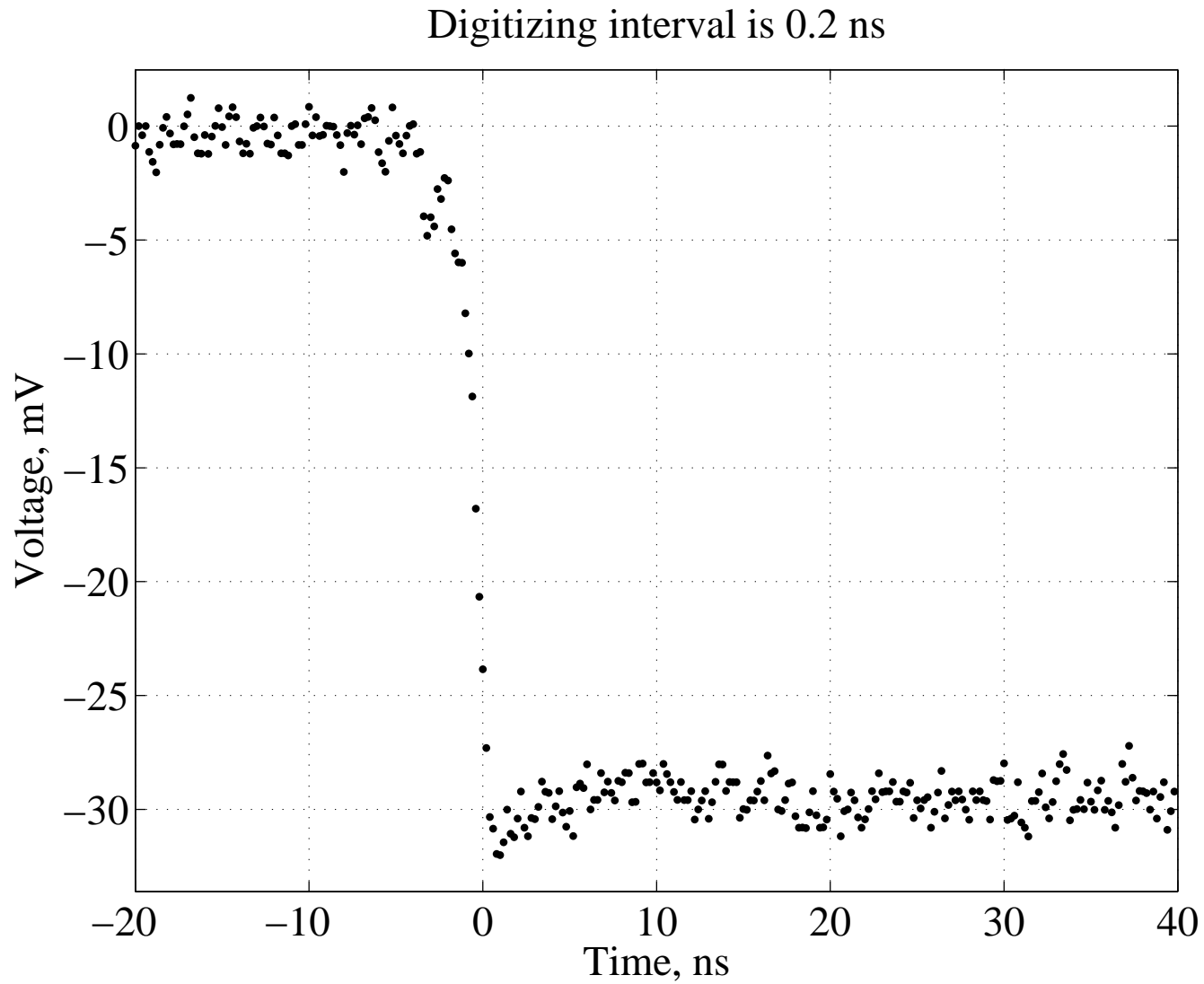


Integrated OA charge-sensitive preamplifier:

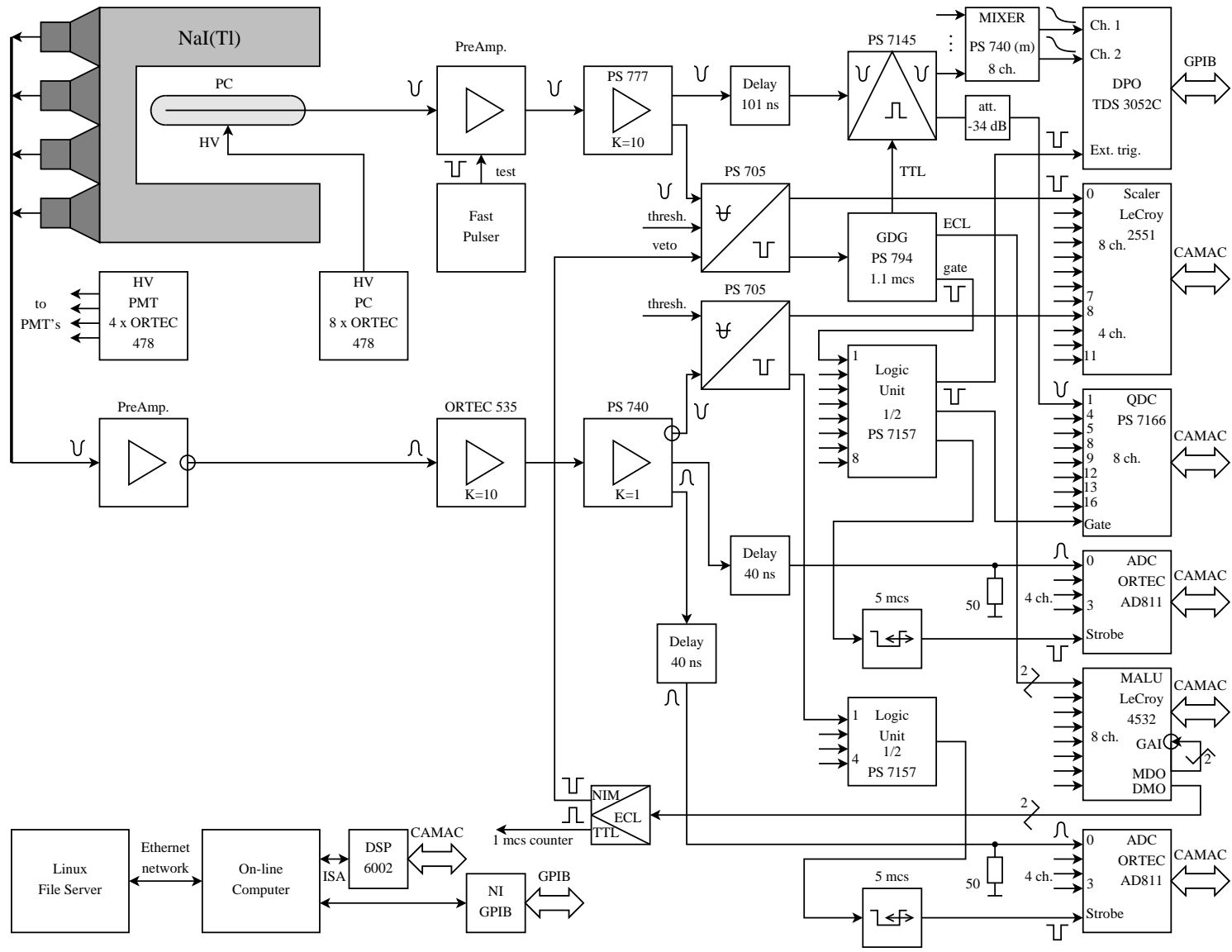
(D. V. Serebryakov, A. A. Shikhin, INR RAS, 2015)



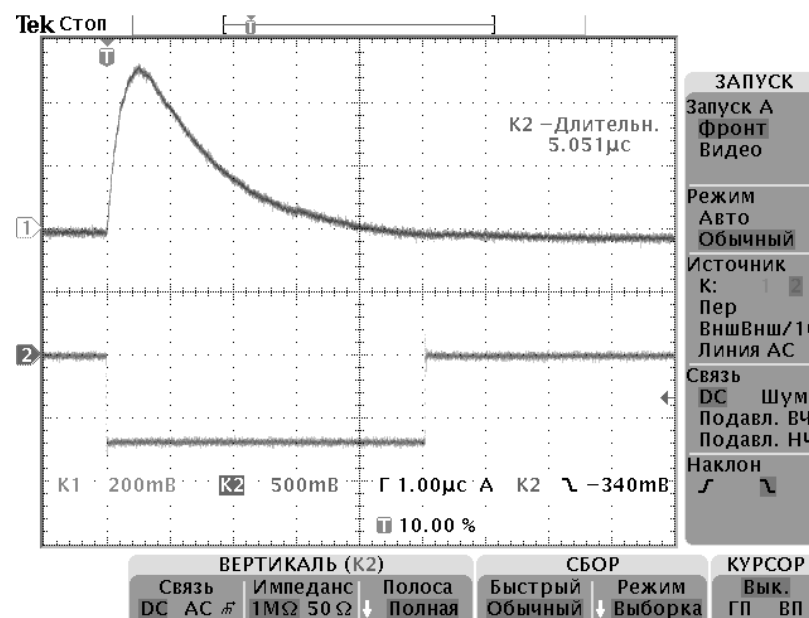
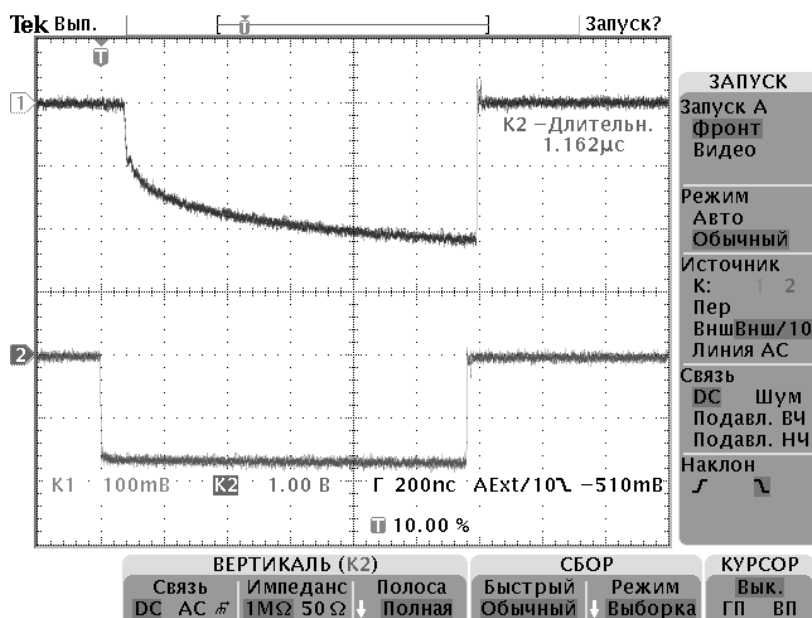
The charge-sensitive preamplifier: risetime response



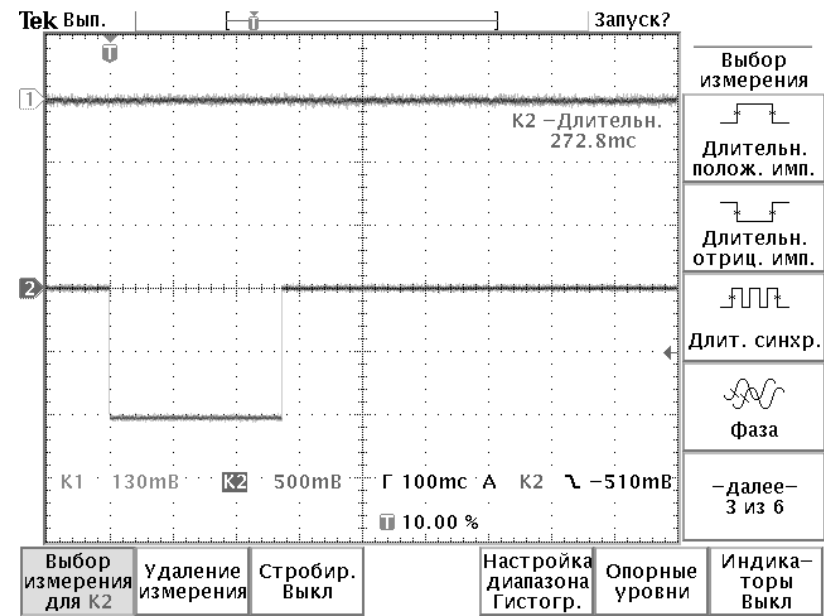
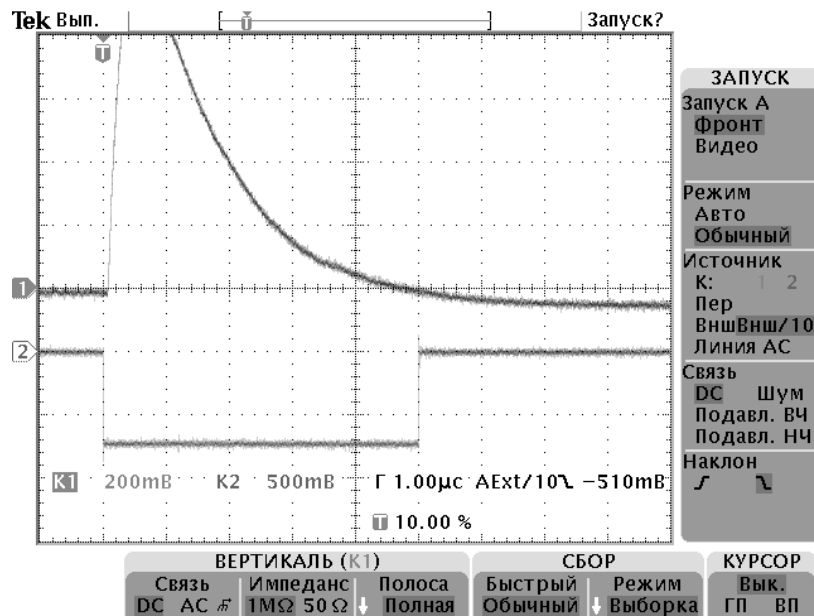
The functional diagram of the system for BEST



The energy of events from the proportional counter (left) and NaI(Tl) (right) measurement



The energy of real coincidence event from NaI(Tl) (left) and veto signal (dead time) measurement



The software of the counting system for BEST

- DOS software (MS DOS, FreeDOS+dosemu+Linux).
 - Utility for PMT gain calibration and bkg of the NaI(Tl) detector measurement.
 - Utility for check of proportional counters operation and their calibration.
 - Utility for check of TDS 3052 DPO operation and pulse shapes recording from counters.
 - On-line software for simultaneous calibration of all installed proportional counters.
 - On-line software for rare events registration.
 - The full set of software for the SAGE counting system are in using also.
- The Geant 4 model for anticoincidence system.

Main performance data of the system for BEST

| | |
|--|------------------|
| Number of counting channels | 8 |
| Energy range (counter channel), keV | 0.3–16 |
| Bandwidth (pulse shape recording channel), MHz | >125 |
| Risetime (pulse shape recording channel), ns | <3 |
| Digitizing frequency (pulse shape recording channel), GHz | 1(5 max) |
| Frame volume (pulse shape recording channel), points | 1000 (10000 max) |
| Digital resolution of DPO (pulse shape recording channel), bit | 2×8(9 max) |
| Digital resolution in the “Energy” channel, bit | 11(12 max) |
| Gate width in the “Energy” channel, ns | 1100–1200 |
| Dead time, ms | 270 |
| Digital resolution in NaI channel, bit | 10(11 max) |
| Shaping time constant in NaI channel, μ s | 1.1 |
| Anticoincidence gate width, μ s | 5 |
| Energy range (NaI channel), keV | 60–3000 |

Current status of the BEST system

1. 8 counting channels in real operation.
2. The first extractions samples counting from both volumes of the BEST target.
3. The second extractions samples counting.
4. The background measurement of new installed counters.
5. Complete software integration to standard data analysis.
6. The system polishing by the “fine file” continues.