# HPGe detector mass calibration with a dissolved uranium source

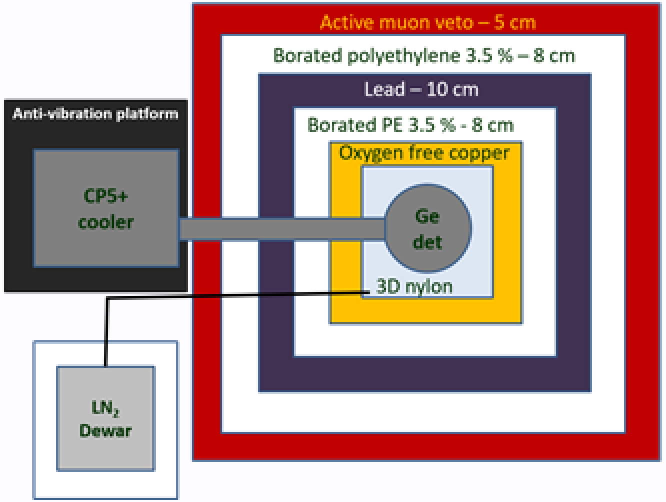
Khussainov Temirlan

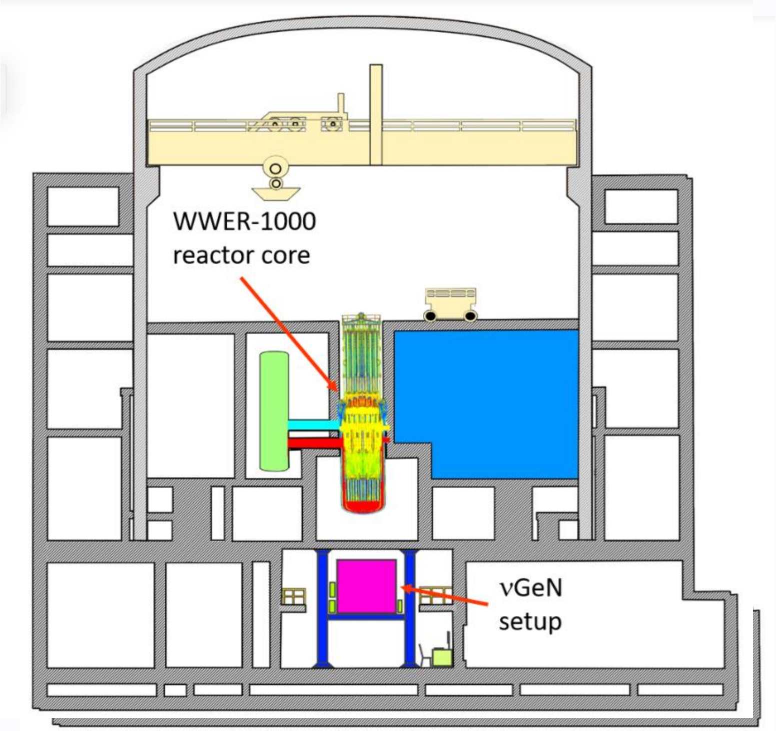
- A distributed uranium source was used to calibrate the HPGe detector identical to one from νGeN experiment.
- The main advantage of such source is very well known activity of $^{238}U$ equal to 12440 ± 12 Bq/g

# About νGeN



- νGeN experiment at the KNPP is aimed at searching for coherent elastic scattering of reactor neutrinos off germanium nuclei.
- The detection of CEνNS requires a largeneutrino flux, a low background, large target mass, and a low energy threshold.

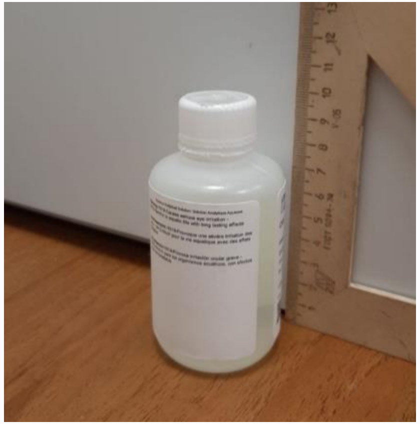


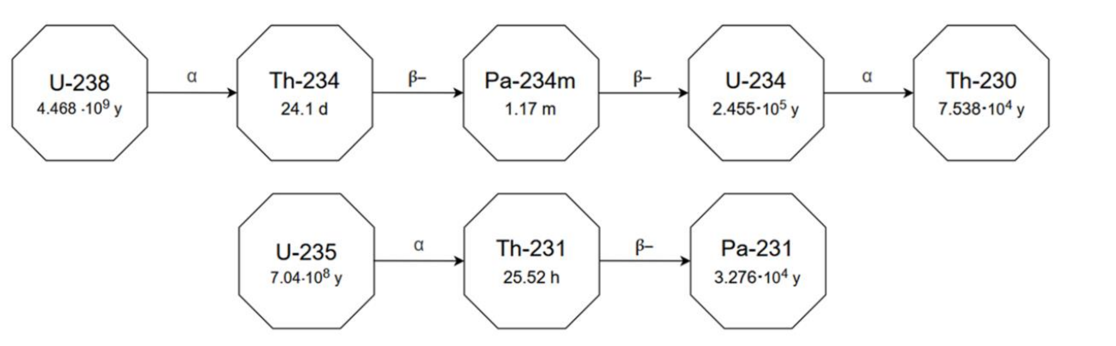



# *Source description*

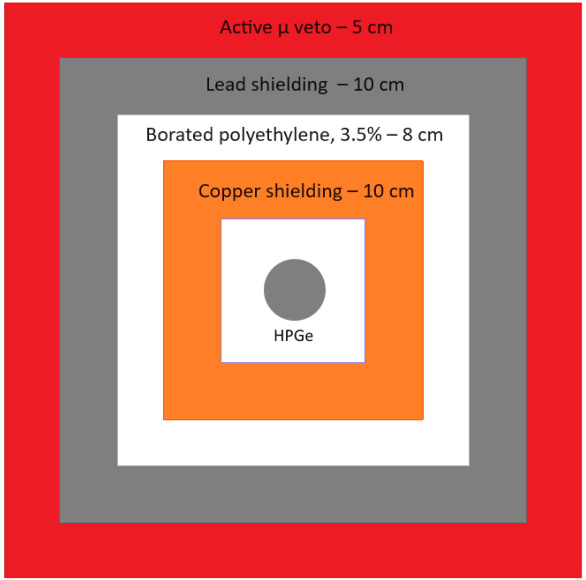


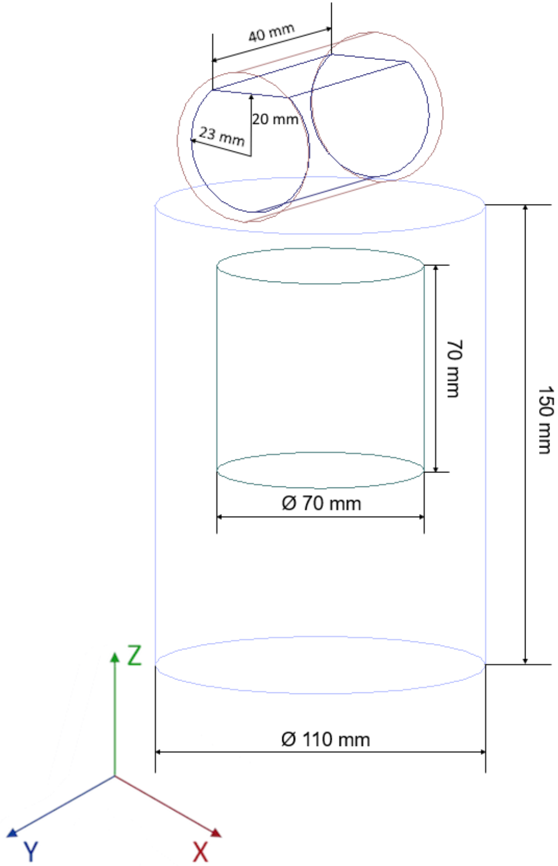
| Parameter | Value |
|---|---|
| Volume | 125 mL |
| Density | 1.010 g/mL |
| Volume concentration $HNO_3$ | 2 % |
| Uranium concentration | 1000 ± 5 $\mu$g/mL |
| $^{238}$U activity | 1555 ± 8 Bq |



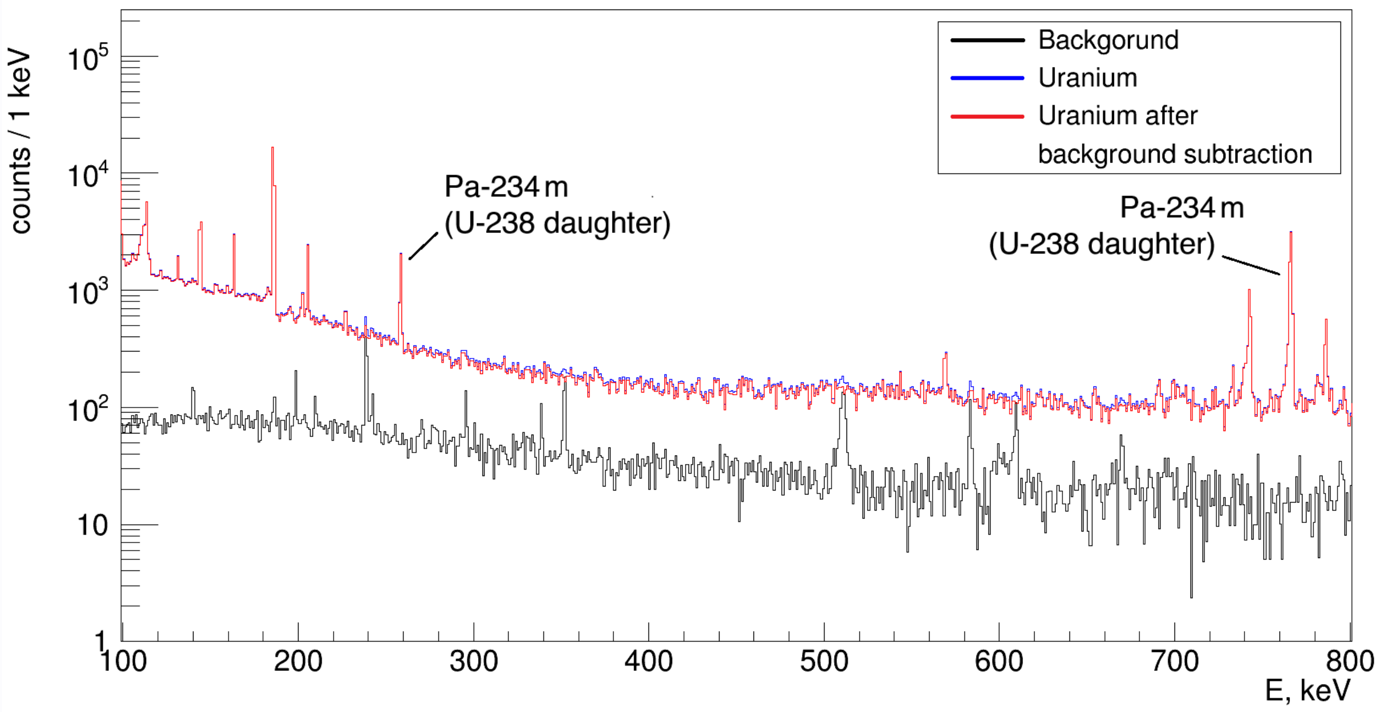


- The measurements were carried out on a low-background setup using a HPGe detector identical to the νGeN detector with a declared mass of 1.4 kg and declared dead layer of 0.5 mm.



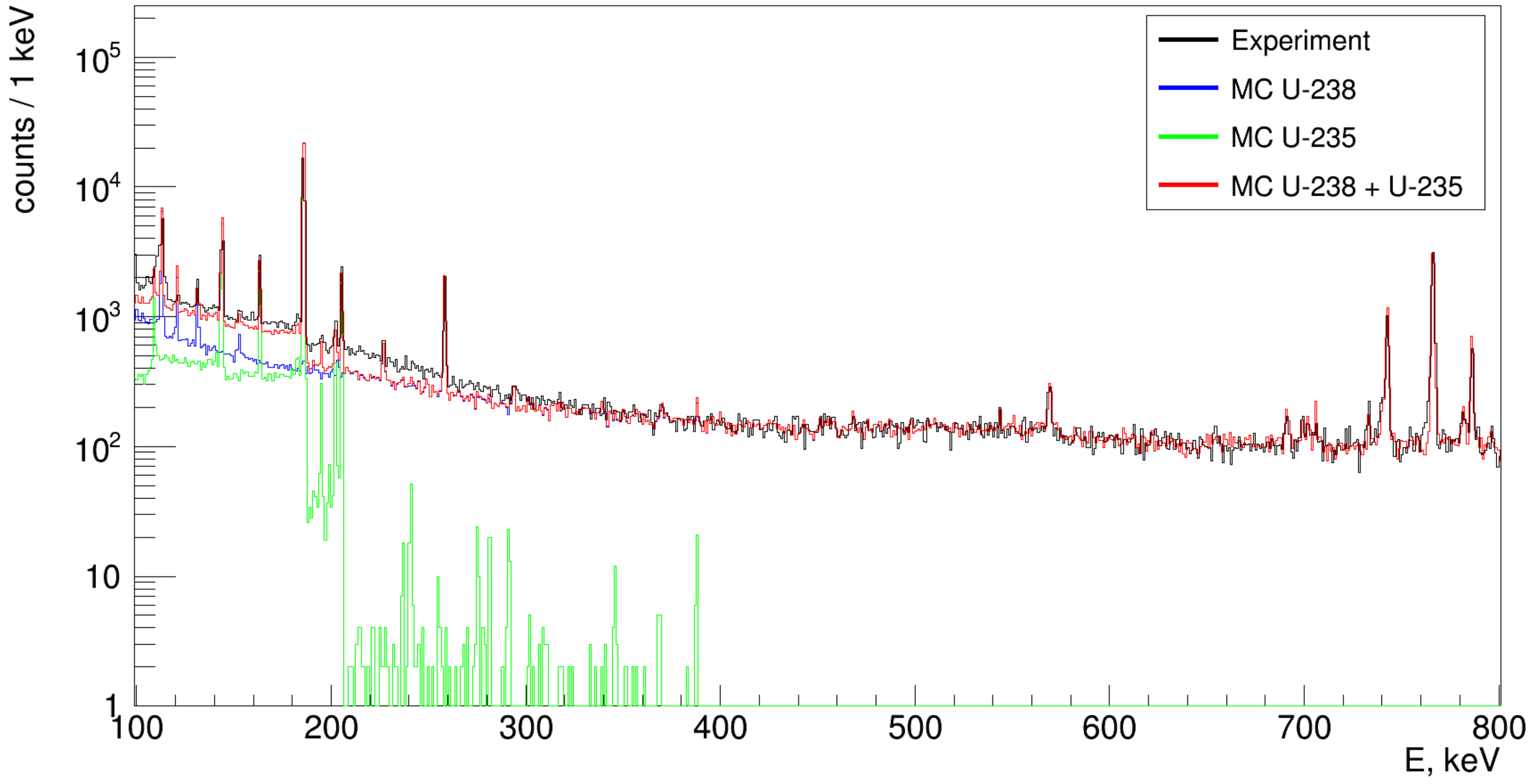



- The background conditions were measured over 10 days, and the measurements with the uranium source lasted 24.4 hours.



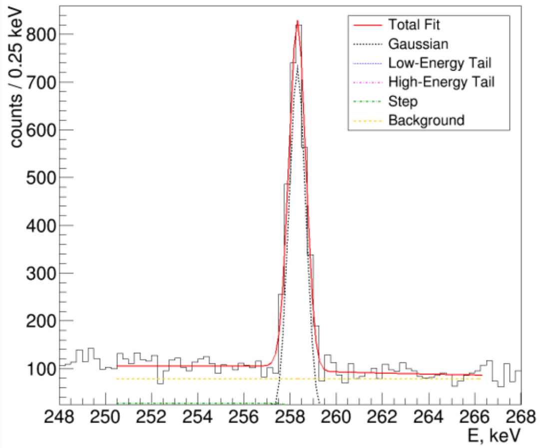
# Experimental and MC spectra comparison

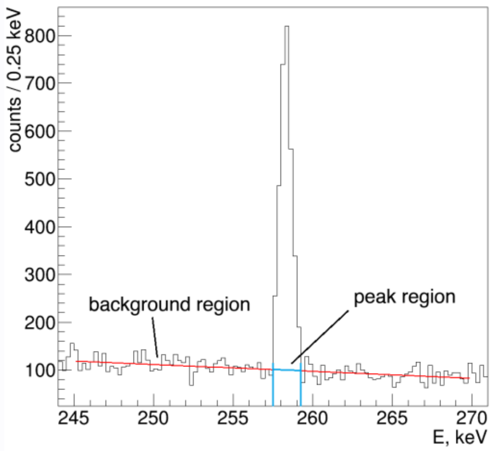


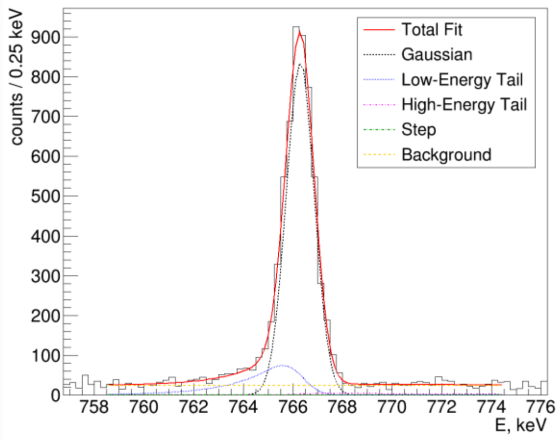


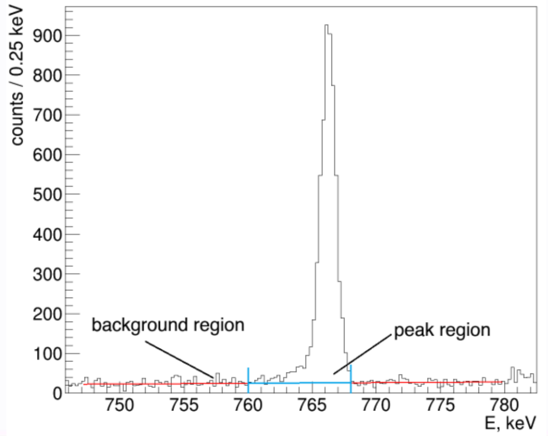
# Analysis




counts / 0.25 keV
E, keV
Total Fit
Gaussian
Low-Energy Tail
High-Energy Tail
Step
Background


counts / 0.25 keV
E, keV
background region
peak region


counts / 0.25 keV
E, keV
Total Fit
Gaussian
Low-Energy Tail
High-Energy Tail
Step
Background


counts / 0.25 keV
E, keV
background region
peak region

Comparison of counts (fitting method).

| E, keV | Experiment | MC | Ratio |
|---|---|---|---|
| 258.26 | 2797 ± 62 | 2731 | 1.02 ± 0.02 |
| 766.36 | 5688 ± 108 | 5952 | 0.96 ± 0.02 |

Comparison of counts (simple method).

| E, keV | Experiment | MC | Ratio |
|---|---|---|---|
| 258.26 | 2637 ± 76 | 2731 | 0.97 ± 0.03 |
| 766.36 | 5735 ± 88 | 5952 | 0.96 ± 0.02 |

- The efficiency calculated in Geant4 is consistent with the experimental data within the errors.
- One can consider ~5% as an additional uncertainty in the νGeN experiment related to the effective mass of the crystal.

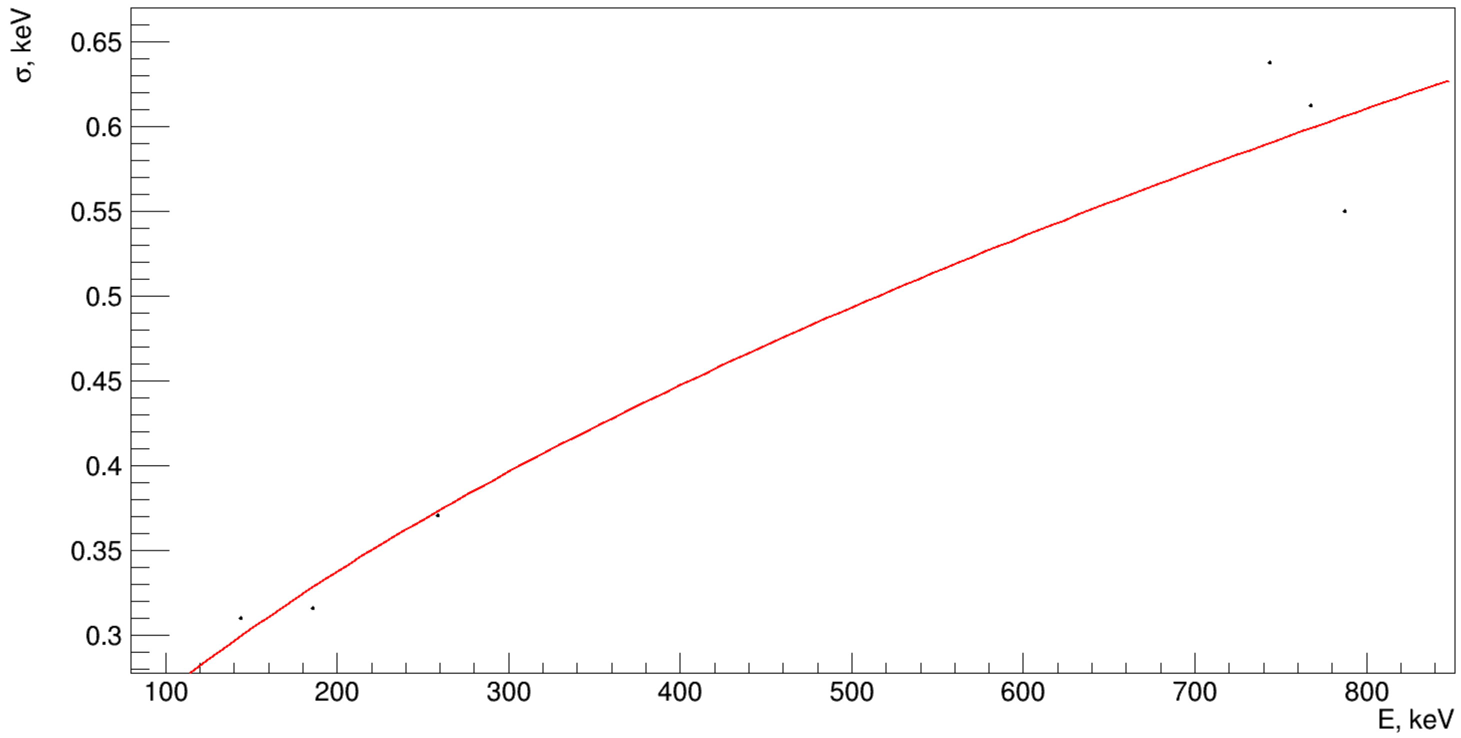
# Conclusion

- As a result of the calibration measurements performed with the distributed $^{238}U$ source of known activity (accuracy at the level of 0.5%), the conformity of the mass of the HPGe detector used in the νGeN experiment with its nominal specification has been verified.
- The applicability of the calibration method using a distributed source for determining the effective mass of germanium detectors has been demonstrated.

# Thank you for attention

# Калибровочная кривая





## 2 Single- and multi-peak shape fitting

An energy calibration can be performed by measuring moments of spectral peaks or by fitting a Gaussian distribution to the peaks. The principal ingredient is a Gaussian function

$$\mathrm{G}(E) = \frac{A(1 - f_{\mathrm{LE}} - f_{\mathrm{HE}})}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(E-\mu)^2}{2\sigma^2}\right) \tag{2.1}$$

where,

- $\mu$ = mean of Gaussian function,
- $\sigma$ = standard deviation of Gaussian function,
- $A$ = peak area; total number of counts in the Gaussian and tail functions, and
- $(1 - f_{\mathrm{LE}} - f_{\mathrm{HE}})$ is the fraction of the total peak area in the Gaussian function, where $f_{\mathrm{LE}}$ and $f_{\mathrm{HE}}$ are the fraction of the total area taken up by the low energy (LE) and high energy (HE) tails subject to the constraint that

$$0 \le f_{\mathrm{LE}} + f_{\mathrm{HE}} \le 1$$

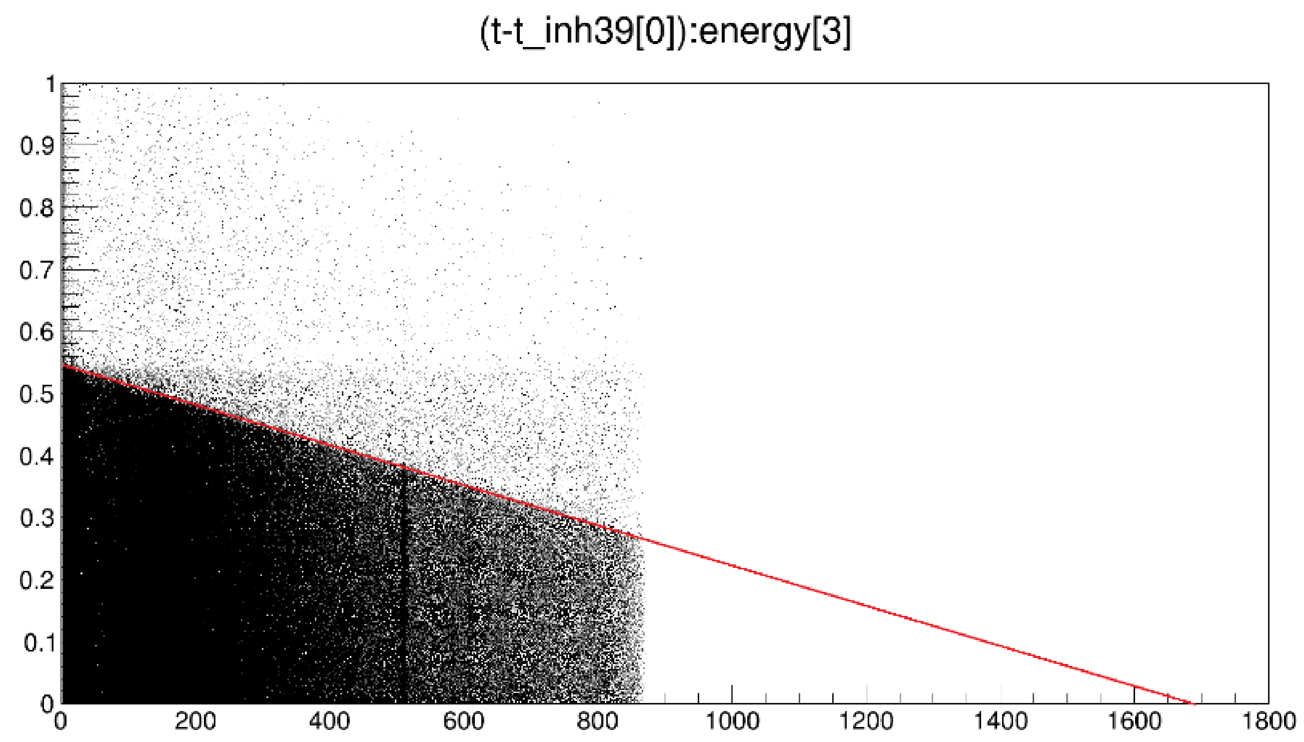
as defined in equation (2.2) and following.

HPGe detector peaks often have features such as low energy tails and steps underneath the peaks that can introduce biases in calibration parameters obtained using a simple Gaussian function, degrade energy resolution by misaligning peak shapes or result in inaccurate estimates of the detection efficiency for a chosen region of interest. The tail functions are represented by the exponentially modified Gaussian function, in which an exponential distribution with tail length $\gamma_\alpha$ is convolved with a Gaussian using the same parameters as the Gaussian peak shape component, such as

$$\mathrm{T}_\alpha(E) = \frac{A f_\alpha}{2\gamma_\alpha} \exp\left(\frac{\sigma^2}{2\gamma_\alpha^2} \pm \frac{E-\mu}{\gamma_\alpha}\right) \operatorname{erfc}\left(\frac{\sigma}{\sqrt{2}\gamma_\alpha} \pm \frac{E-\mu}{\sqrt{2}\sigma}\right) \tag{2.2}$$

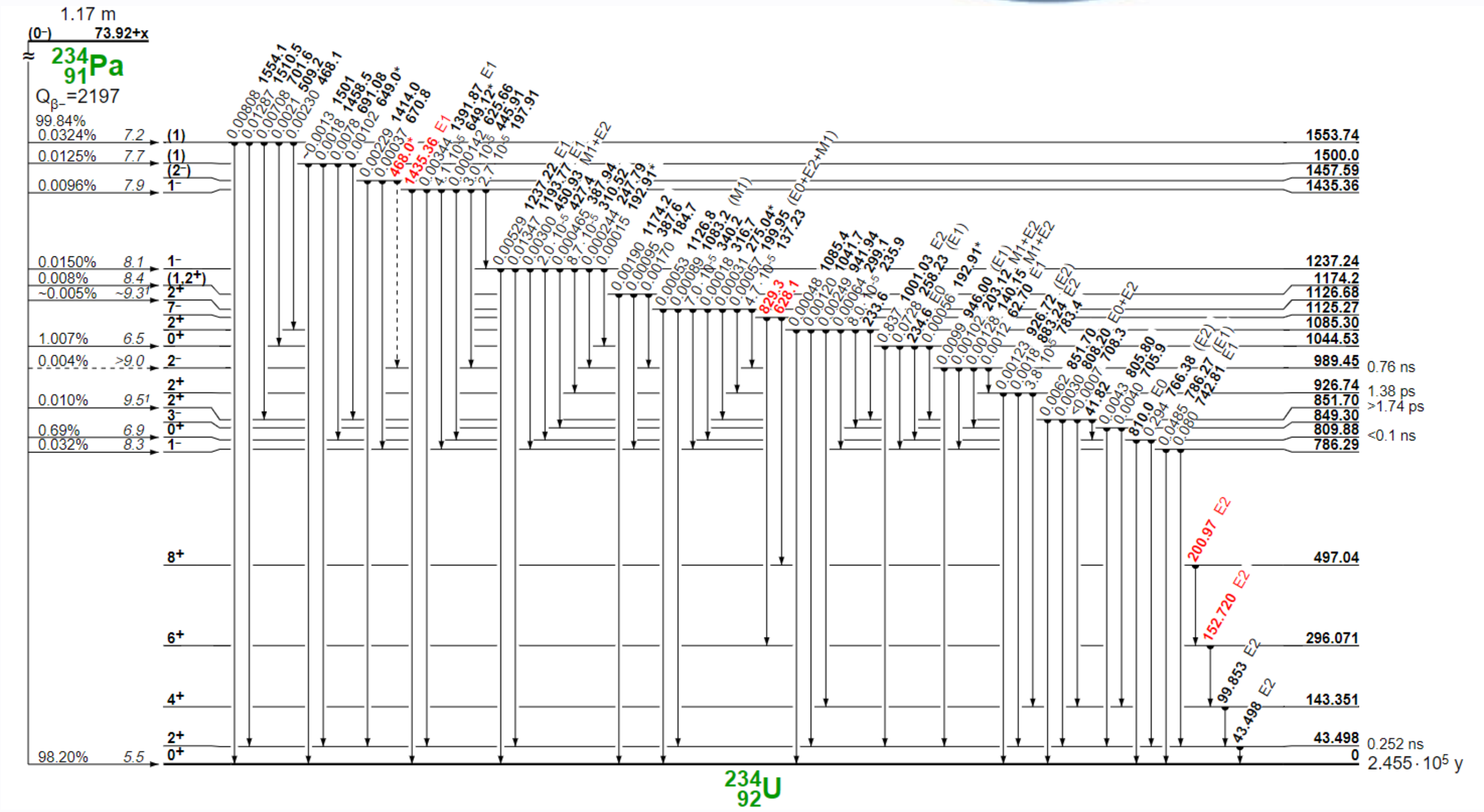
where,

- $\alpha$=LE(+), HE(-), the signs of which correspond to the choice of $\pm$ above, and
- $\gamma_{\mathrm{LE}}$ or $\gamma_{\mathrm{HE}}$ = decay constant of the LE/HE tail exponential.


(t-t_inh39[0]):energy[3]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
1400
1600
1800

# Переходы в Pa-234





# Схема электроники