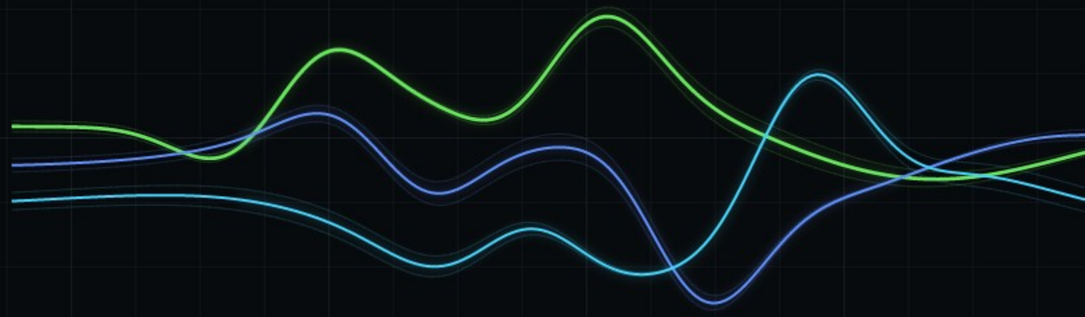
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Gamma spectrometry

My experiments with SIPM-based gamma ray detection



Pavel Pernička
BUT FEEC

BRNO UNIVERSITY OF TECHNOLOGY

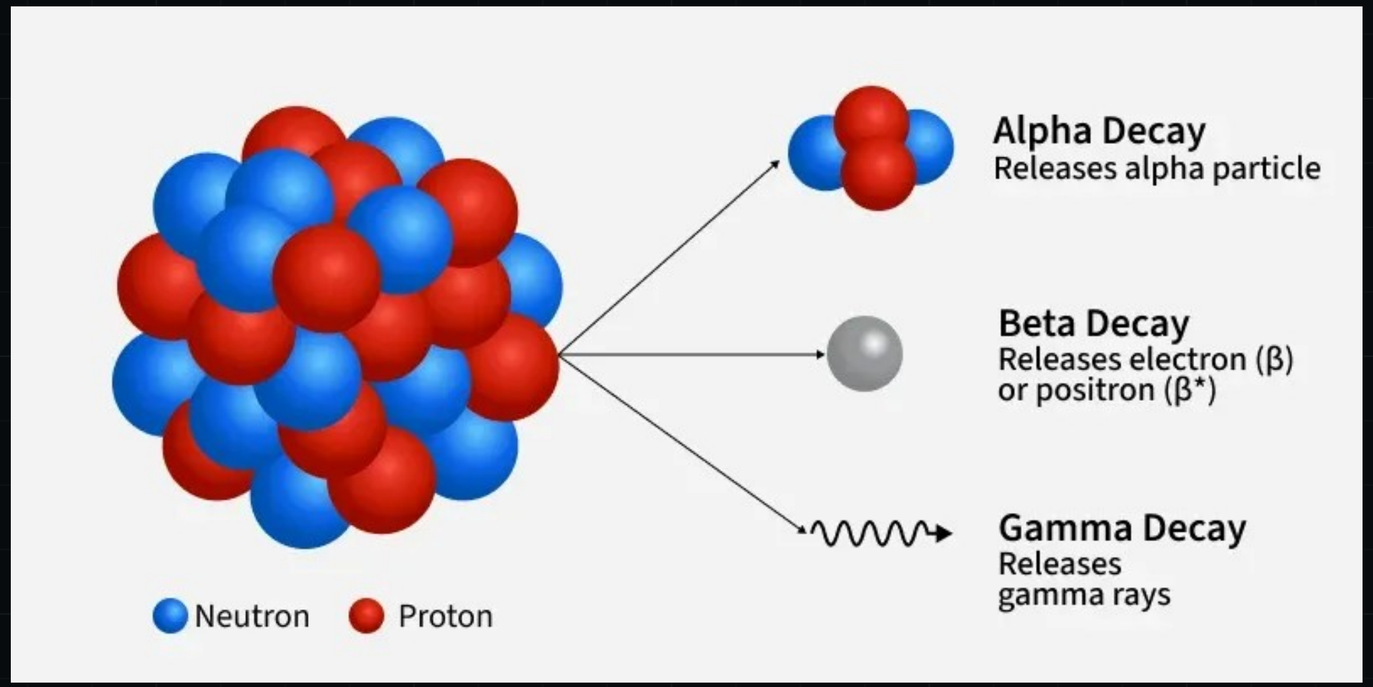
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01

Theoretical background



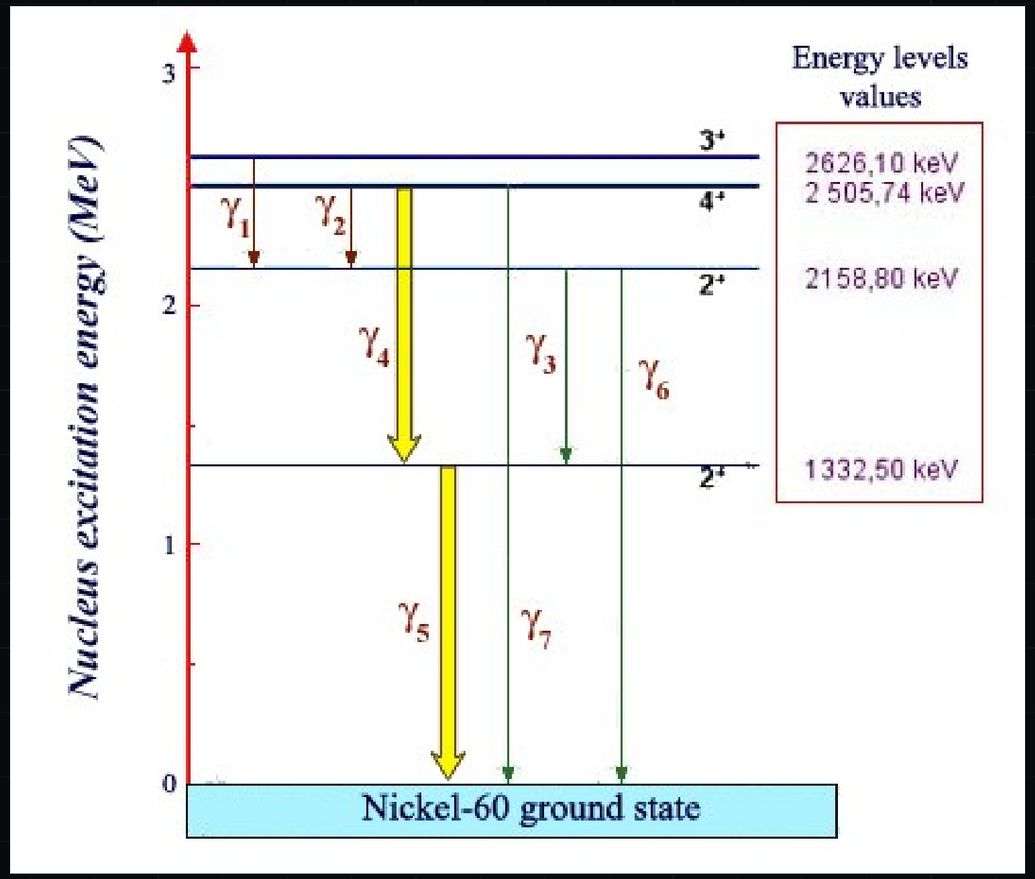
Radioactive decay



Unstable nucleus → spontaneous decay

3 main types, gamma often accompanies alpha and beta

Gamma transition



Transition between nucleus energy states

Allowed transitions – characteristic photon energies (useful)

During de-excitation from previous process

Example: ^{60}Co

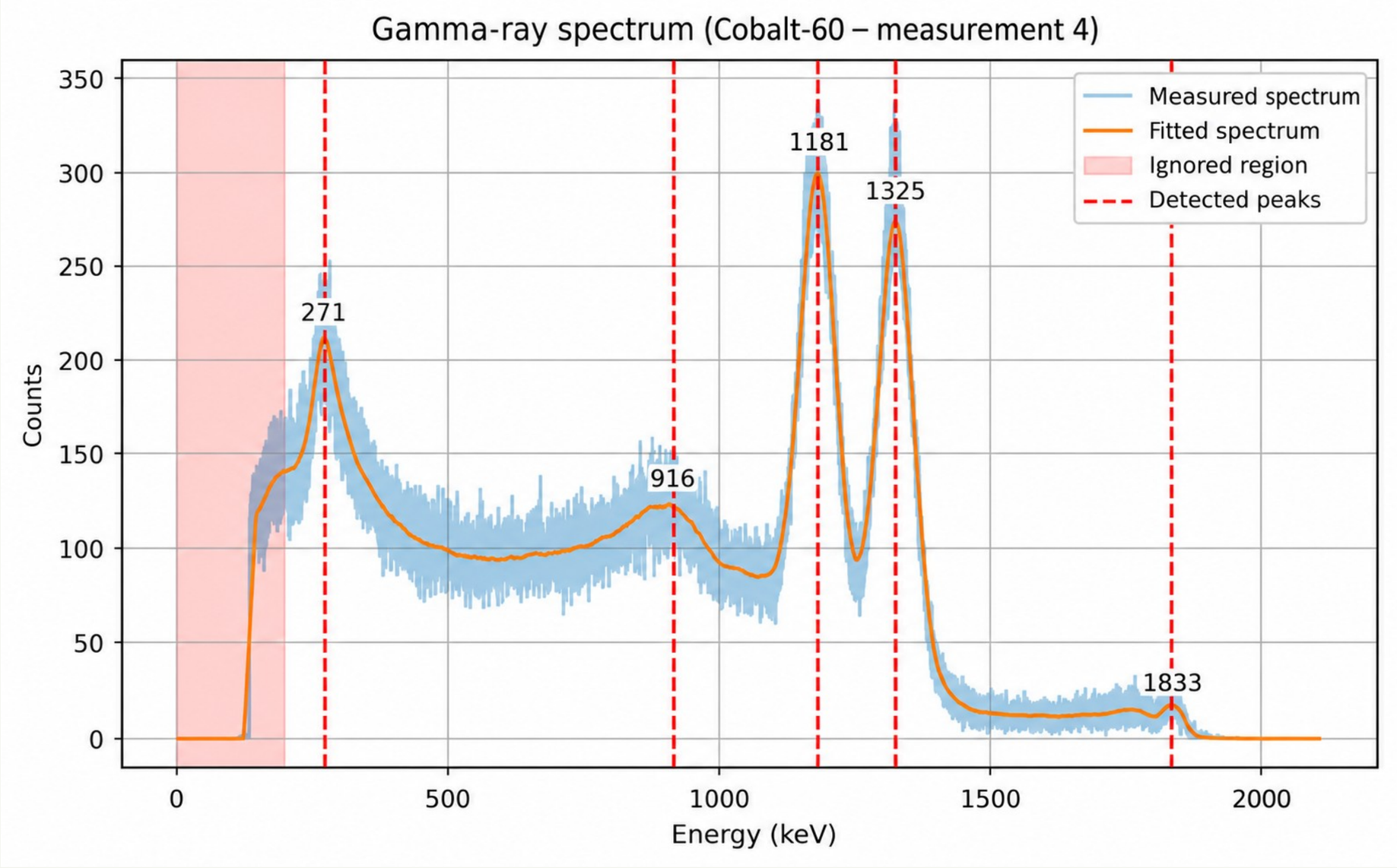
Decay:

$$^{60}\mathrm{Co} \xrightarrow{\beta^-} {}^{60}\mathrm{Ni}^* + e^- + \bar{\nu}_e.$$

De-excitation:

$$^{60}\mathrm{Ni}^* \longrightarrow {}^{60}\mathrm{Ni} + \gamma_1 + \gamma_2,$$

E_1=1173 keV E_2=1332 keV


Gamma-ray spectrum (Cobalt-60 – measurement 4)
Measured spectrum
Fitted spectrum
Ignored region
Detected peaks
271
916
1181
1325
1833
Counts
Energy (keV)
0
50
100
150
200
250
300
350
0
500
1000
1500
2000

Where can we find gamma-ray energies?

Gamma

#	E_γ [keV]	I_γ-(abs) [%]	Initial level [keV]	J^π	Final level [keV]	J^π	Mult.	δ	α_T
1	347.14 *7*	0.0075 *4*	2505.748 *4*	4+	2158.612	2+	[E2]		0.00557 *8*
2	826.10 *3*	0.0076 *8*	2158.612 *21*	2+	1332.508	2+	M1+E2	0.9 *3*	0.000337 *18*
3	1173.228 *3*	99.85 *3*	2505.748 *4*	4+	1332.508	2+	E2(+M3)	-0.0025 *22*	0.0001722 *25*
4	1332.492 *4*	**99.9826 *6***	1332.508 *4*	2+	0.0	0+	E2		0.0001625 *23*
5	2158.57 *3*	0.0012 *2*	2158.612 *21*	2+	0.0	0+	[E2]		0.000439 *7*
6	2505.692 *5*	0.0000020 *4*	2505.748 *4*	4+	0.0	0+	E4		8.63E-5 *12*

International Atomic Energy Agency Database

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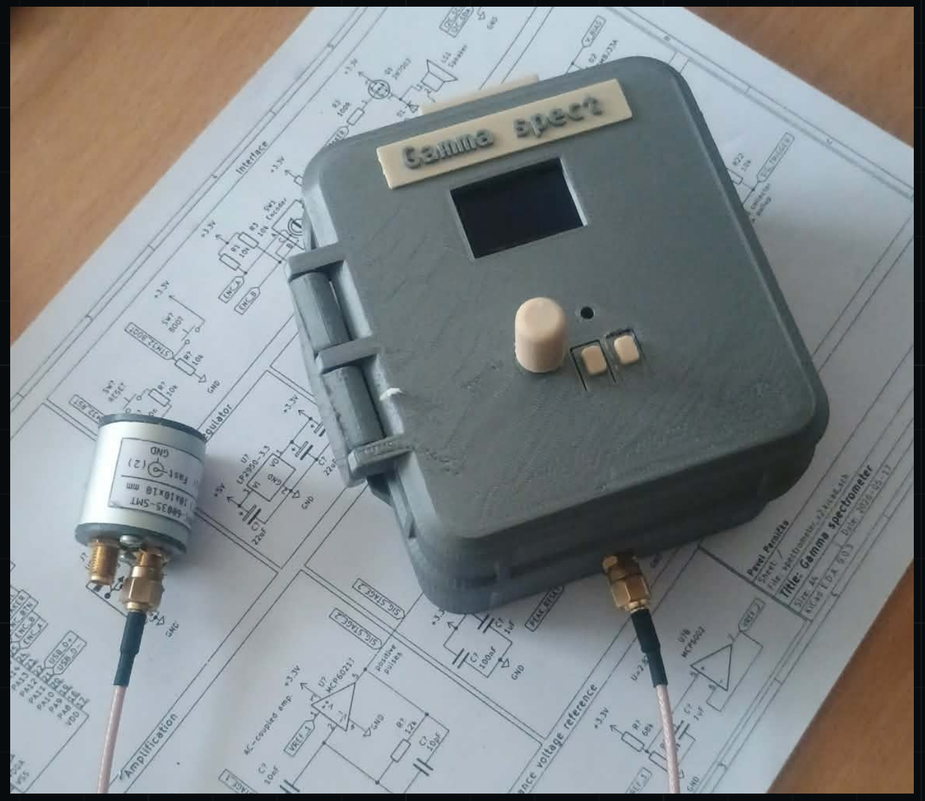
02

How to measure it



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My handheld spectrometer



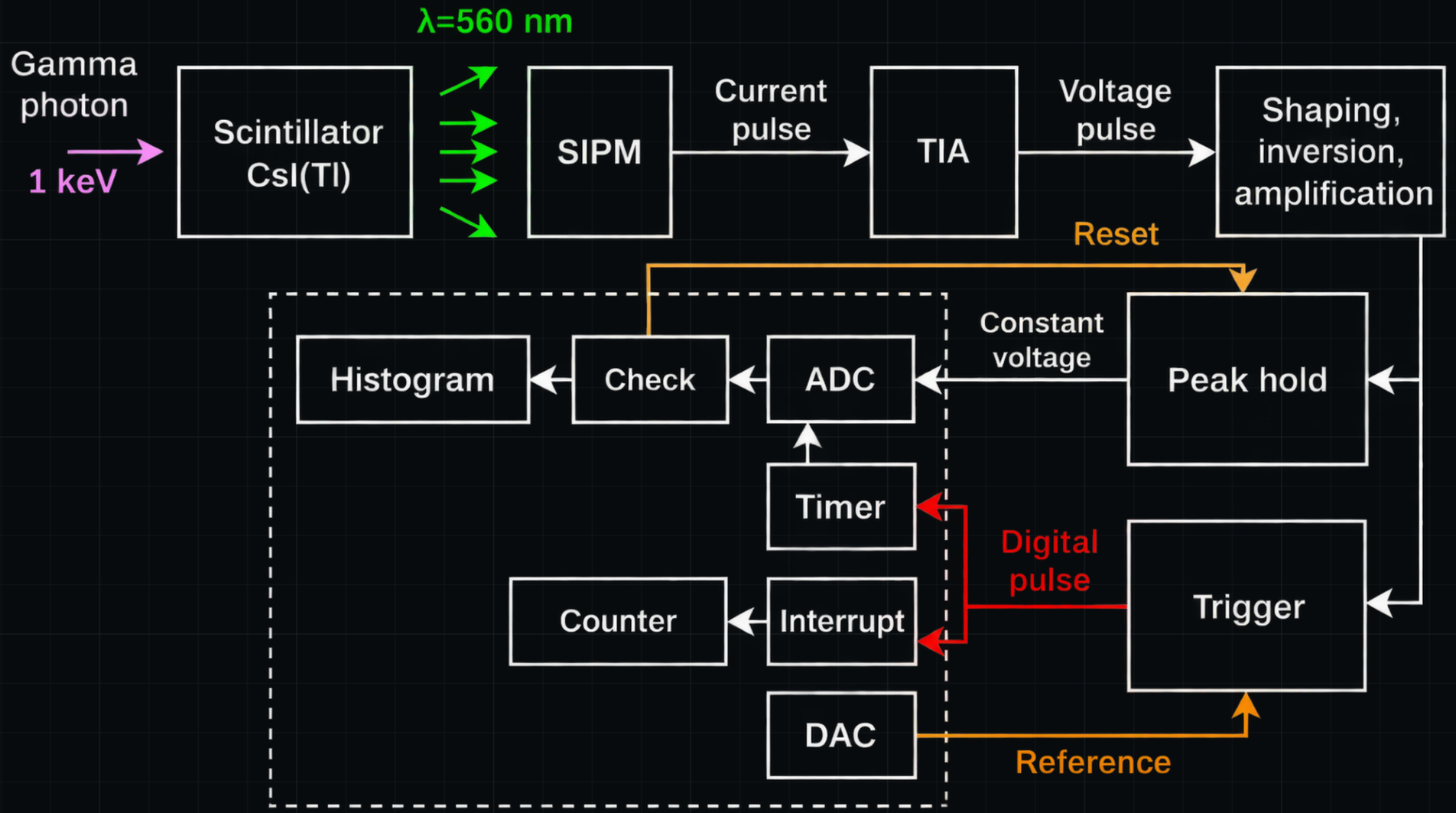
Analog frontend

Integrated DC-DC step-up converter

Fast event detection (peripherals)

STM32

SIPM-based (modern way)


λ=560 nm
Gamma photon
1 keV
Scintillator CsI(Tl)
SIPM
Current pulse
TIA
Voltage pulse
Shaping, inversion, amplification
Reset
Histogram
Check
ADC
Constant voltage
Peak hold
Timer
Digital pulse
Counter
Interrupt
Trigger
DAC
Reference

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Scintilation crystal

CsI(Tl) – commonly used in detectors

Slower impulse

Ca. 65 photons/keV

Green scectrum (maybe problem?)







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SIPM







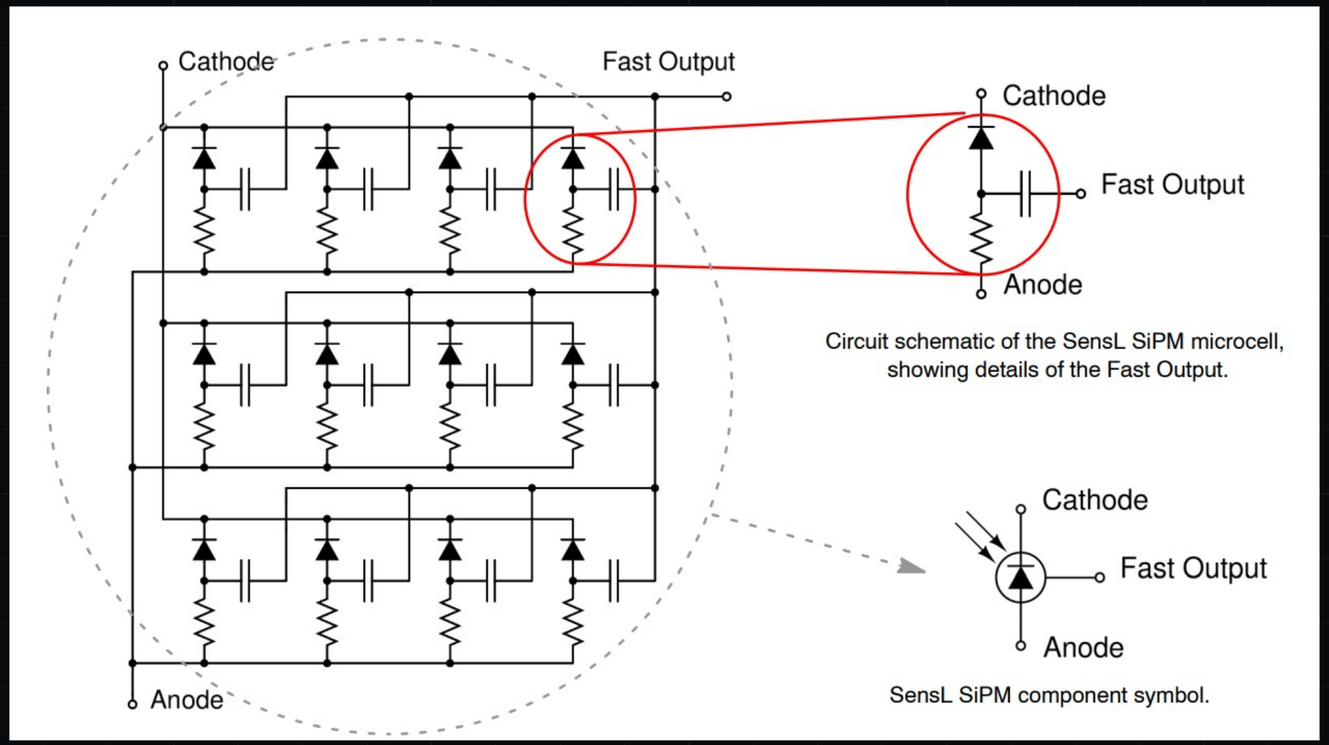


SIlicon PhotoMultiplier
Single photon detection

Alternative for PMT (tube)
Price: ~320 CZK

No high voltage,
Almost no saturation (*)

... and analog frontend + MCU



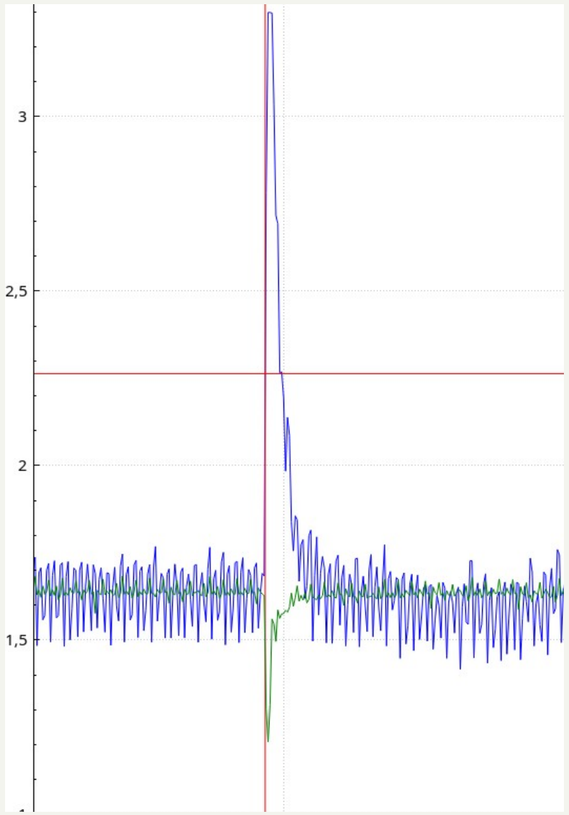
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03
Results

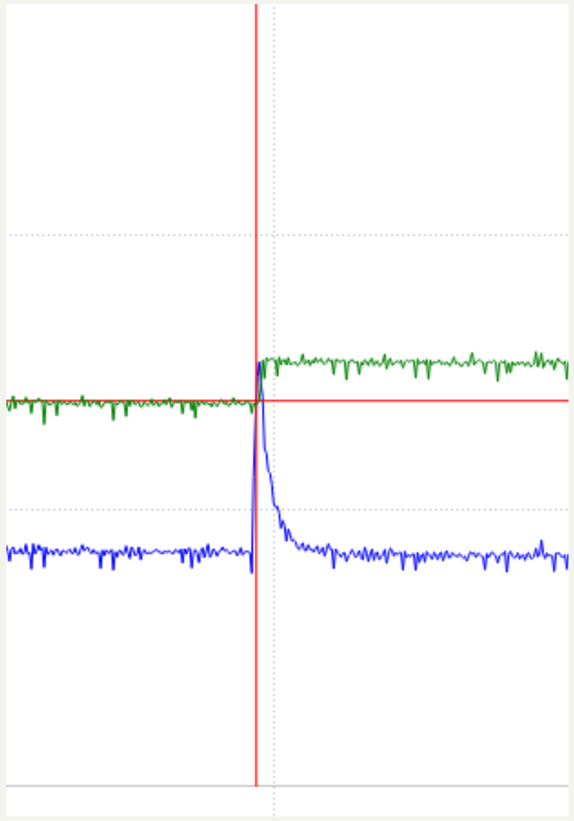


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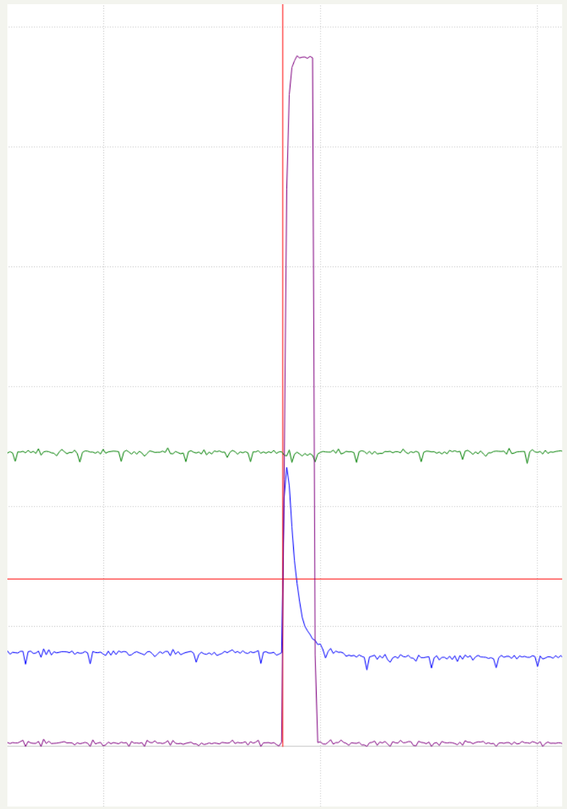
Internal signals



First/second stage amplified signal



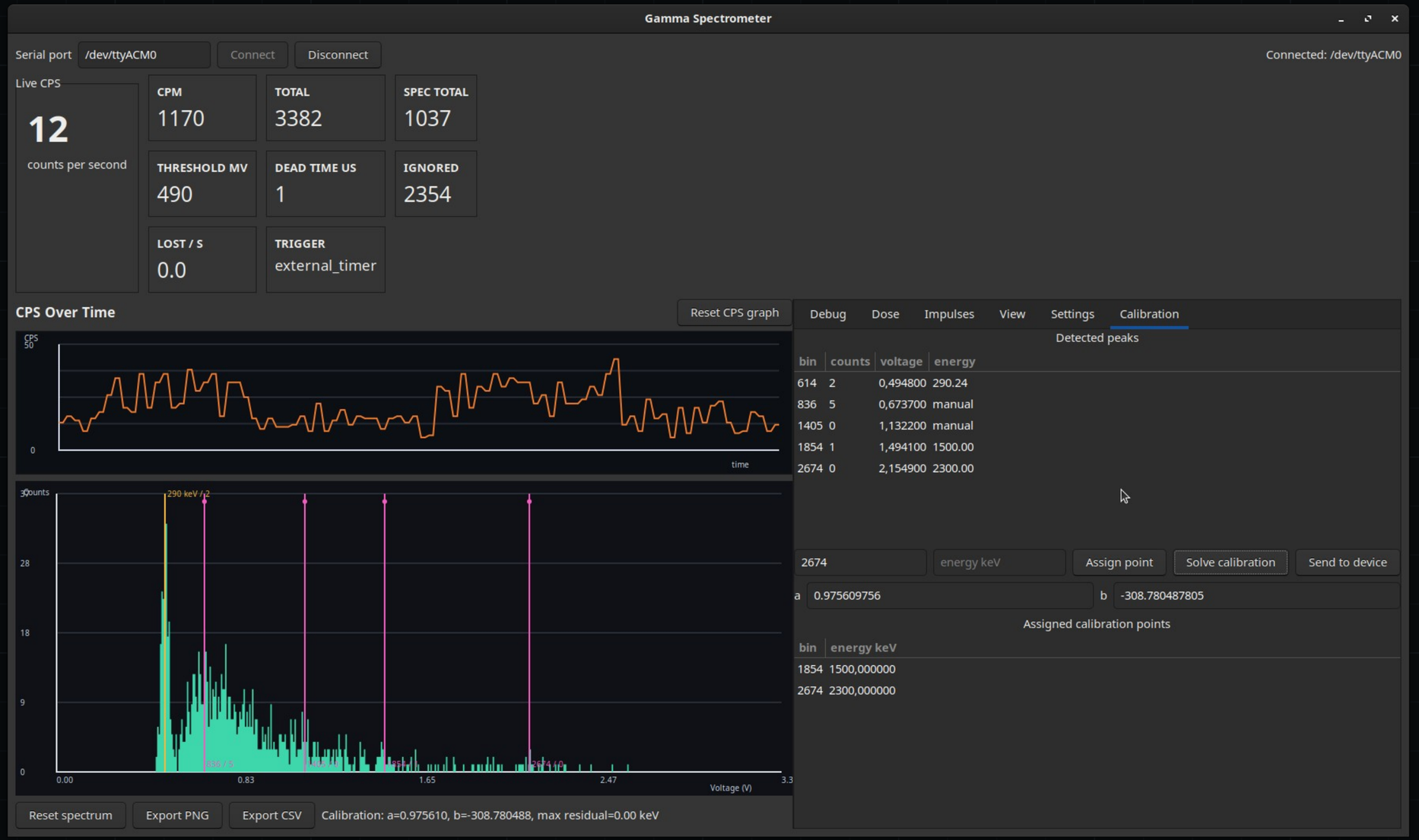
Peak holding



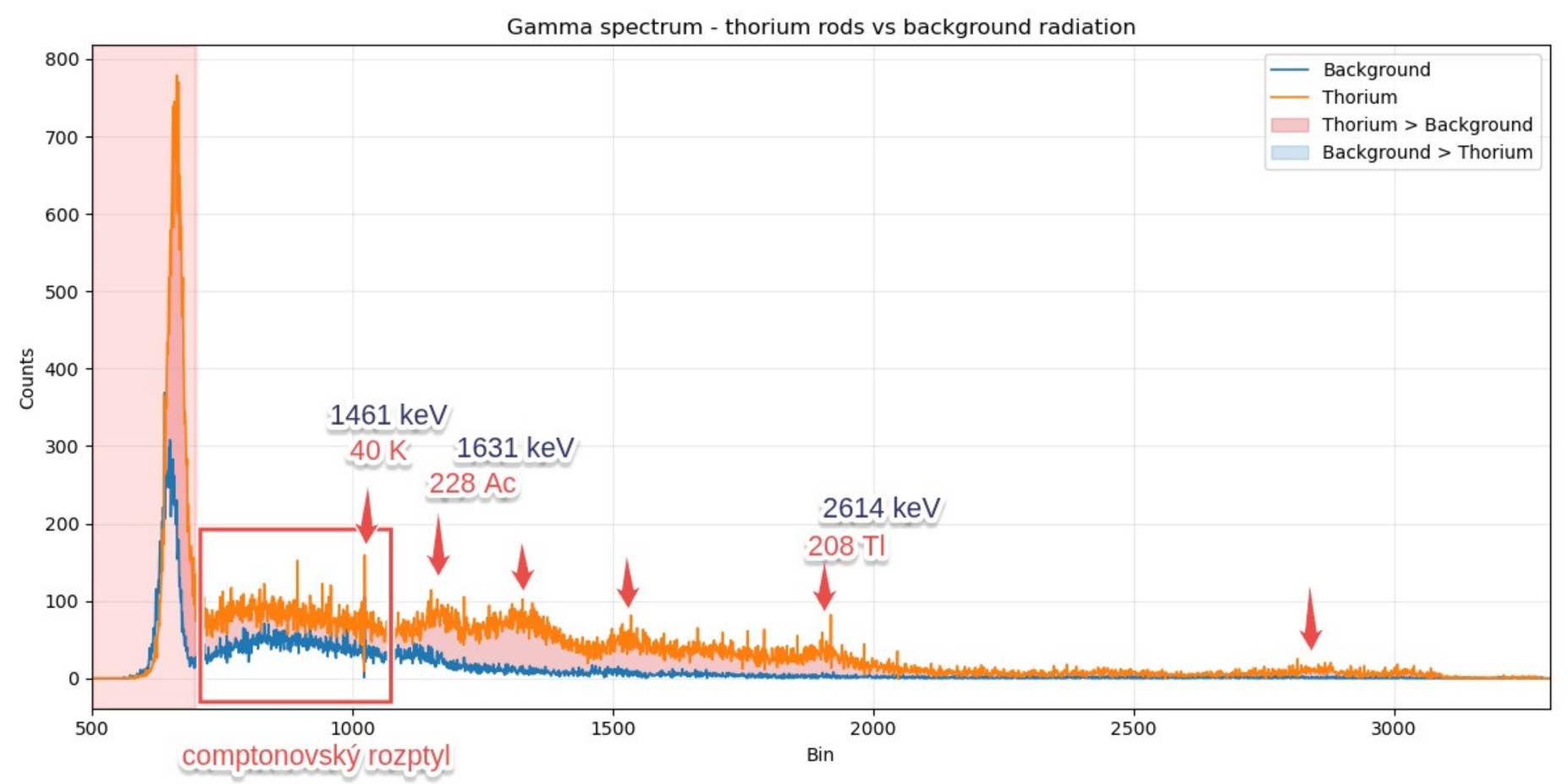
Trigger

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GUI



Measured spectrum



Conclusion

Pros:

Cheap

Precise dose calculation

Identification of strong isotopes

Cons:

Dark noise, analog noise (buck DC-DC)

Wide peaks

Limited range

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Any questions

Thanks for your attention

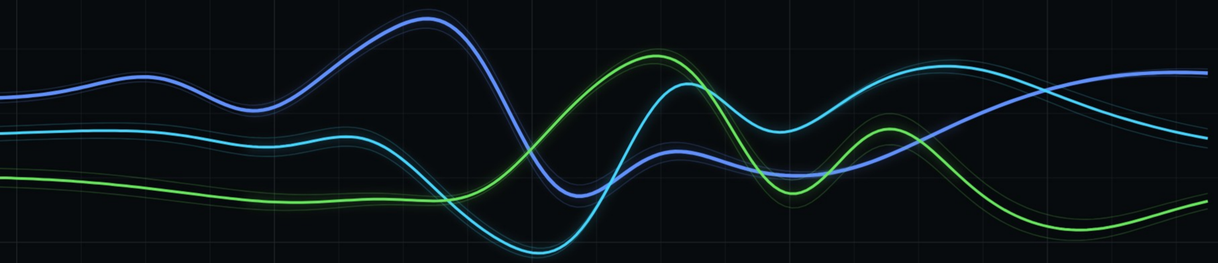


pavel@pernicka.cz

CrossTalk Brno

Student Talk Evenings

Invitation



crosstalk_brno

crosstalk.cz

Date will be announced soon – probably 10th November at T12 building

Short presentations

Variant topics from different people

Place for discussion

You can question freely and give your point of view

Informal atmosphere

Friendly and chill