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Evolution of the background with time in the νGeN experiment

Moscow International School of Physics, Voronovo

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Neutrino experiments at KNPP

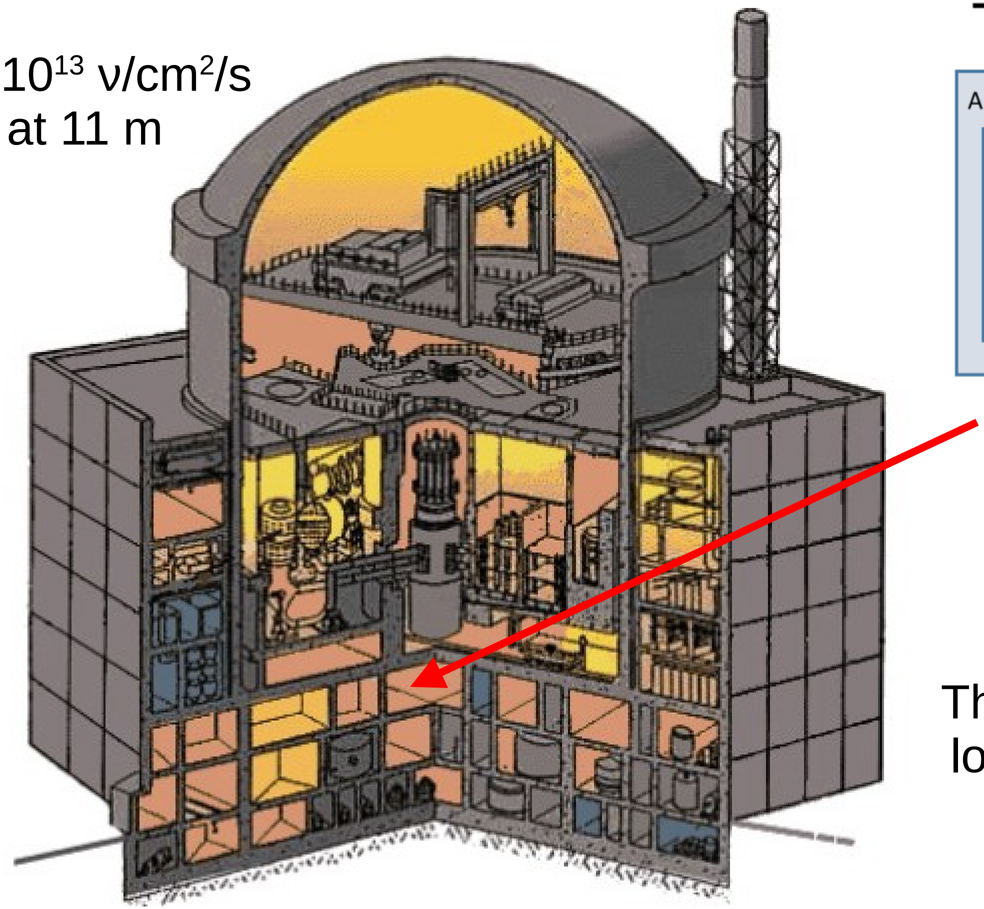
Kalinin Nuclear Power Plant — Udomlya, Tver Region

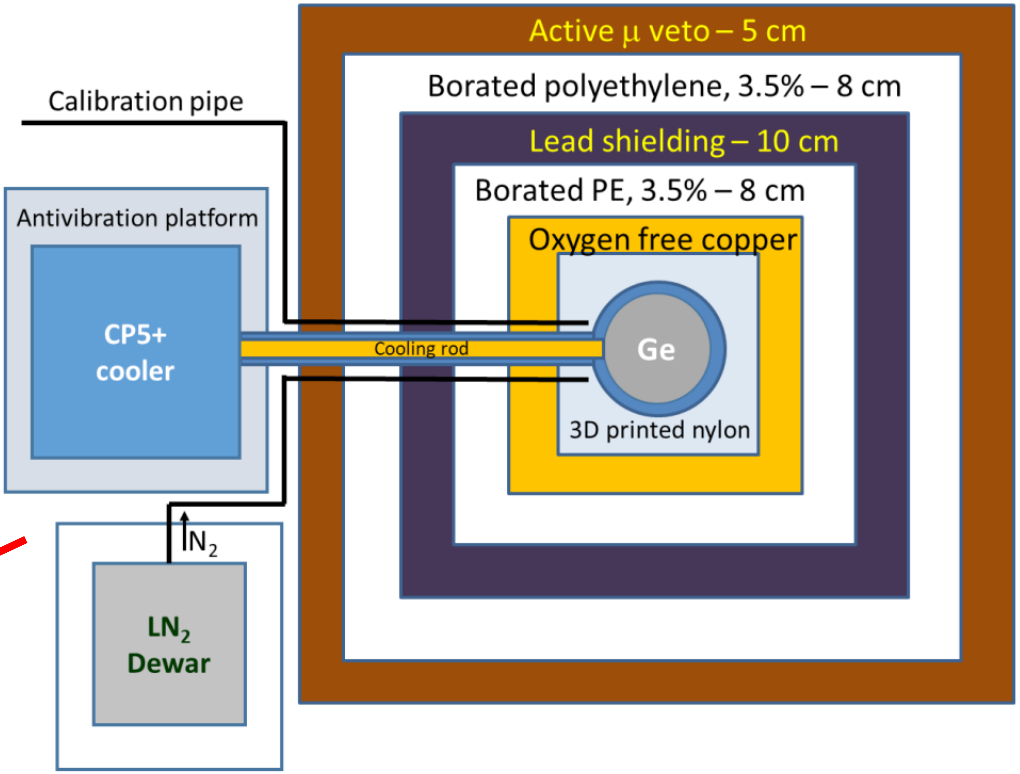
Four neutrino experiments at the same nuclear power plant!

The νGeN experiment

50 m.w.e. of the construction materials above — good supression of CR

$4.4 \cdot 10^{13}$ ν/cm²/s at 11 m

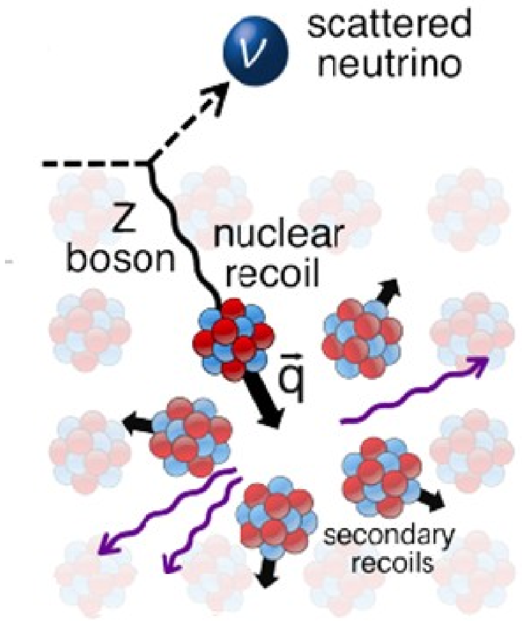




The multi-layered shielding protects the 1.4 kg low threshold (<0.3 keV) HPGe PPC detector from gammas and neutrons

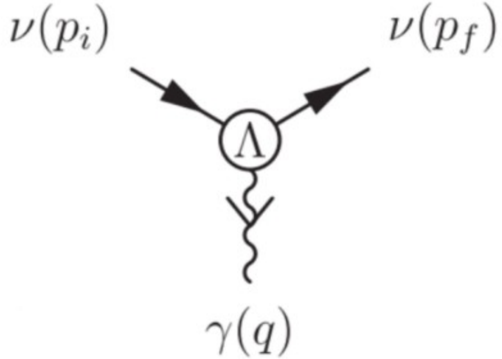
The goals

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS)



νGeN CEvNS limits :
Phys. Rev. D 106, L051101 (2022)
Lomonosov-2023, D. Ponomarev

Neutrino-Magnetic Moment (NMM)



$$\mu_\nu = \frac{3\, e\, G_F}{8\, \pi^2 \sqrt{2}} \cdot m_\nu \approx 3 \cdot 10^{-19} \mu_B \cdot \frac{m_\nu}{1\text{eV}}$$ – SM

BSM + Majorana ν allow $\mu_\nu \sim 10^{-11}\ \mu_B$

$$\frac{d\sigma_{\text{EM}}}{dT} = \pi r_0^2 \left(\frac{\mu_\nu}{\mu_B}\right)^2 \left(\frac{1}{T} - \frac{1}{E}\right)$$

for scattering on electrons

νGeN μ_ν sensitivity and a limit :
MISP-2024, G. Ignatov (poster)

νGeN and competitors

The previous best NMM limit at the reactor is set by GEMMA — $\mu_\nu < 2.9 \cdot 10^{-11}\ \mu_B$ (90% C.L.)

Experiment	Mass, kg	ν flux, $cm^{-2}s^{-1}$	E_{th}, keV_{ee}	Reference
GEMMA	1.5	$2.7 \cdot 10^{13}$	2.8	Adv.High Energy Phys. 2012
νGeN	1.4	$4.4 \cdot 10^{13}$	0.2-0.3	Phys.Rev.D 106 (2022)
COνUS	3.7	$2.3 \cdot 10^{13}$	0.2-0.3	Eur.Phys.J.C 82 (2022)
Dresden-II	2.9	$4.8 \cdot 10^{13}$	0.2-0.3	JHEP 09 164 (2022)

All three new experiments have a chance to set a better NMM limit!

LZ dark matter experiment (solar ν) — $\mu_\nu < 1.5 \cdot 10^{-11}\ \mu_B$ (90% C.L.) Phys. Rev. D 107, 053001 (2023)

Astrophysical considerations — $\mu_\nu < 3.0 \cdot 10^{-12}\ \mu_B$ (90% C.L.) Astrophys. Journal, 365 559 (1990)

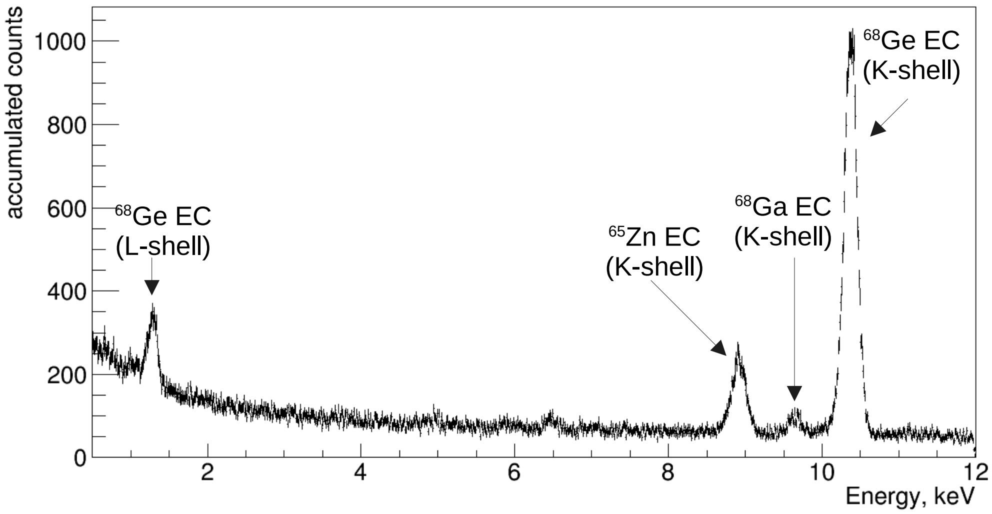
Total νGeN exposure up to 2024 is 1500 kg*d > 1400 kg*d for GEMMA!

Signal vs. background instability

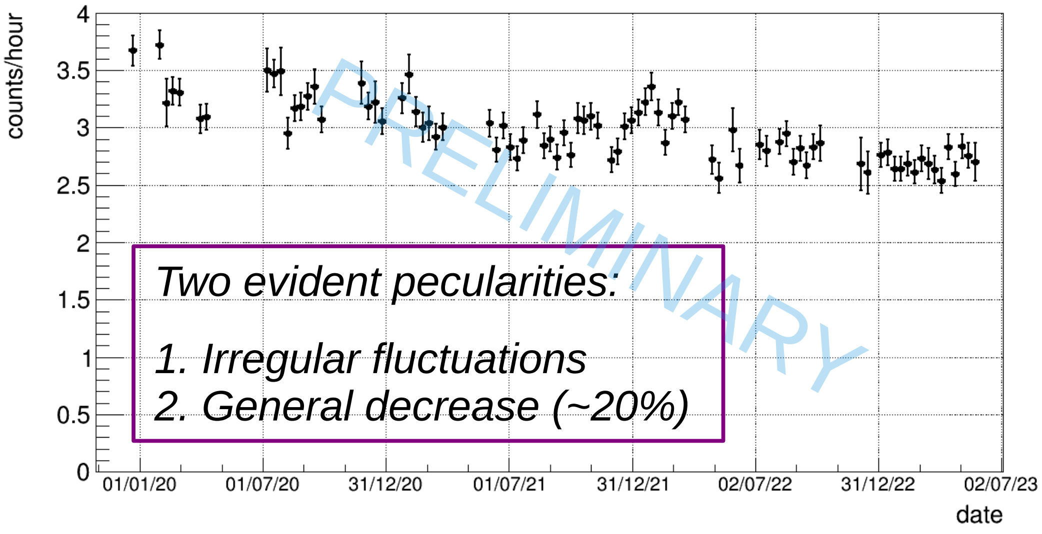
Reactor ON − Reactor OFF = ν signal (NMM, CEvNS) + Reactor BG + Steady-state BG fluct.

νGeN reliably operates since 2020, no evident reactor-correlated BG

Reactor ON spectrum

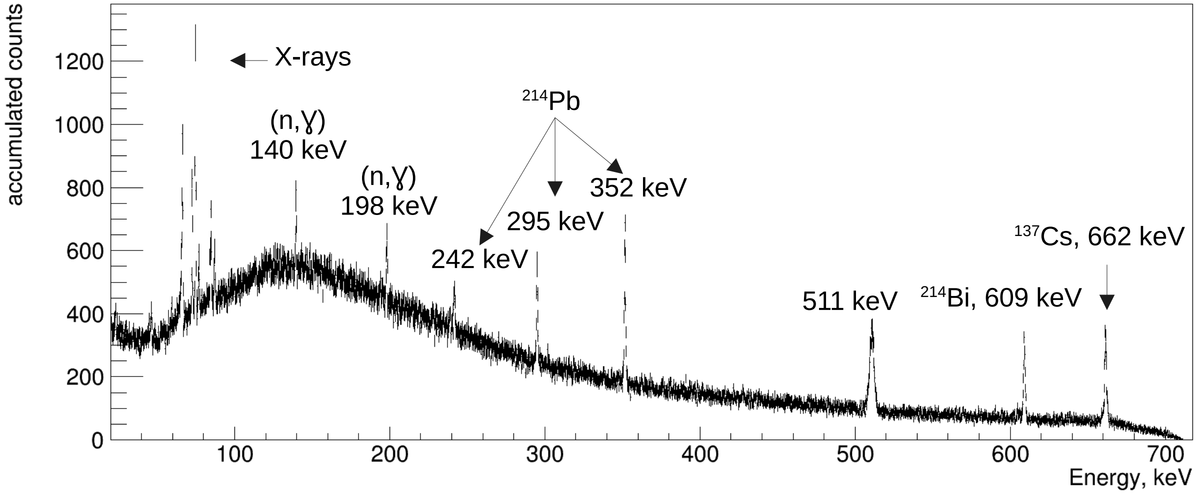


Count rate for 2-8 keV_{ee} vs. time

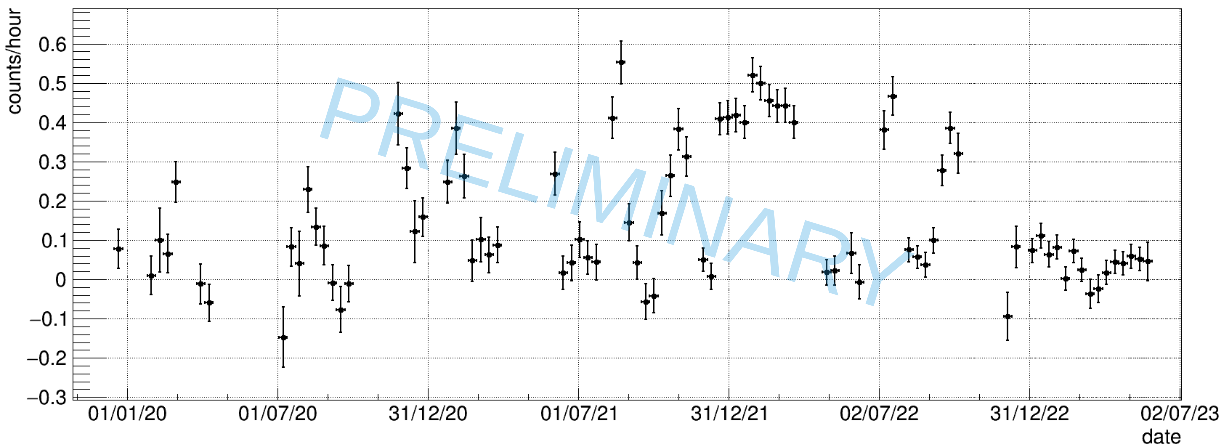


Radon and it's profile

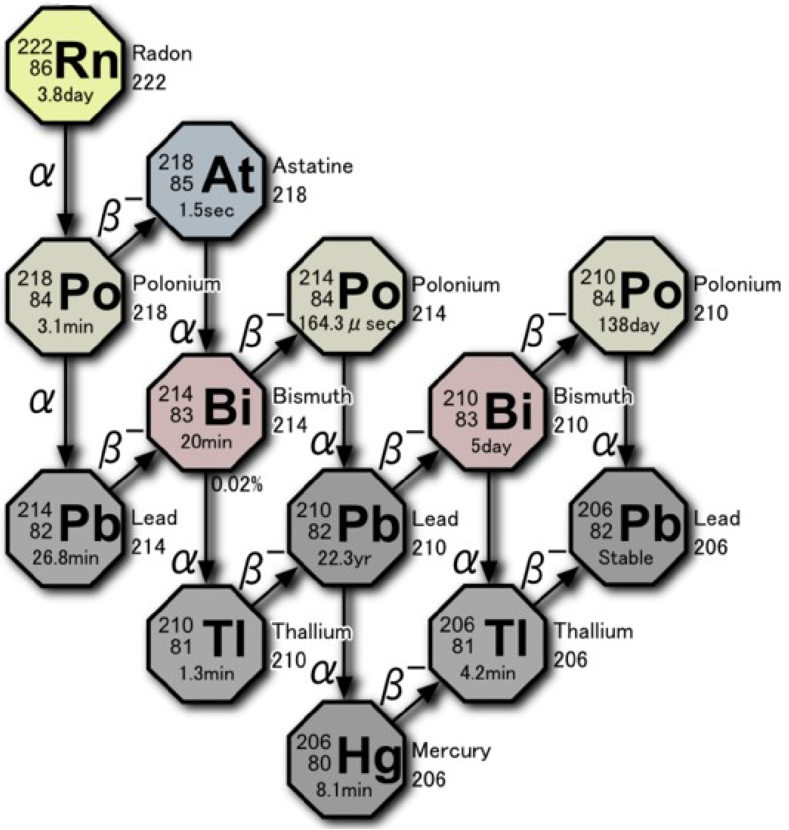
Reactor ON high energy



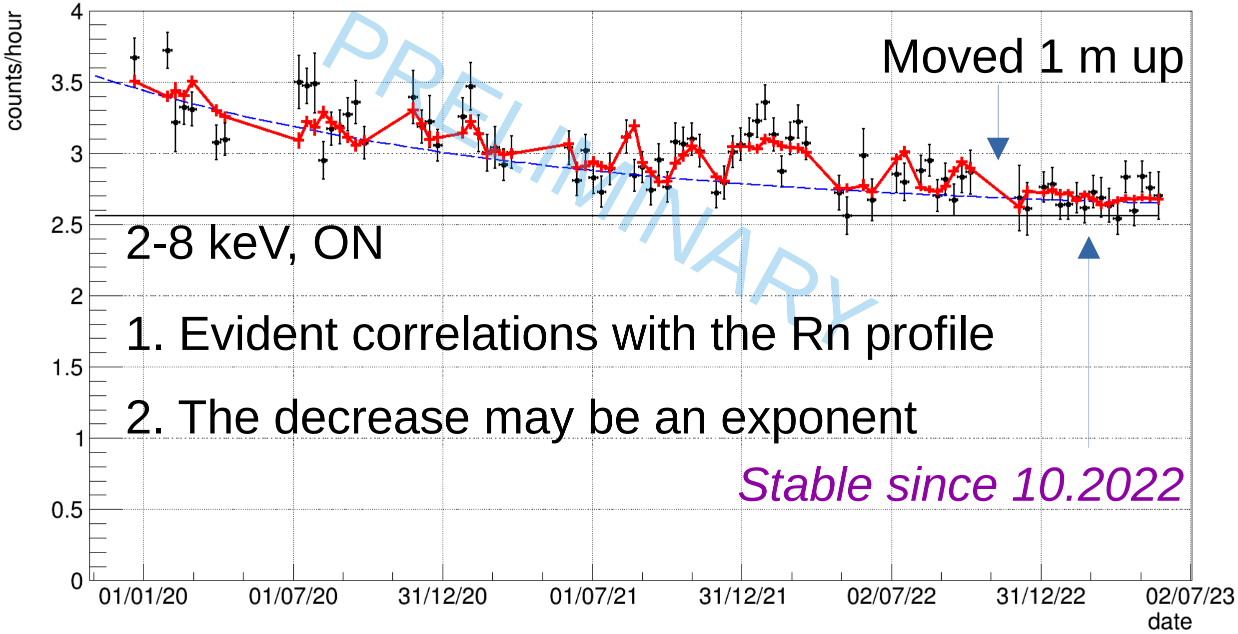
Time profile of Rn, ON



^{222}Rn decay chain



Let’s fit

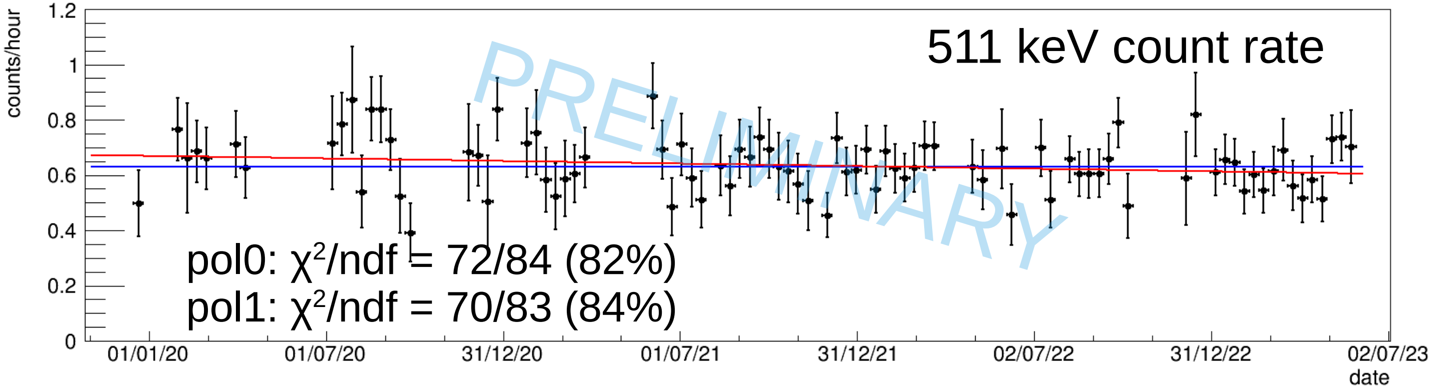


Let’s consider presence of some radioactive isotope, what we know:

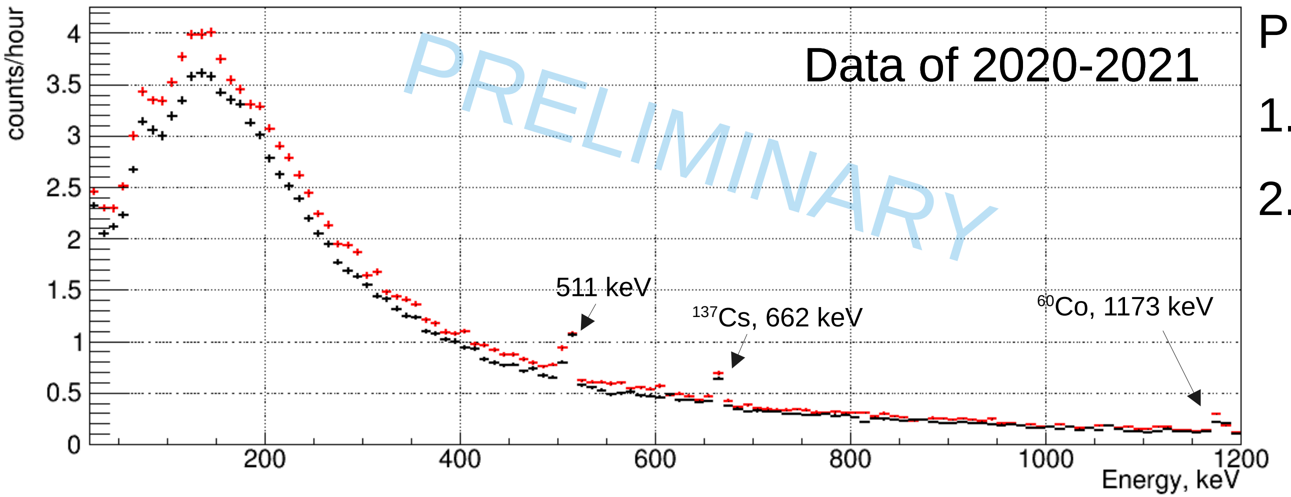
1. $T_{1/2}$ 90%: 260-580 d
2. No unknown photopeaks
3. 511 keV: inconclusive
4. endpoint enegy..?

511s may indicate the nature of the decay mode…

…but they don’t



Residual energy spectrum



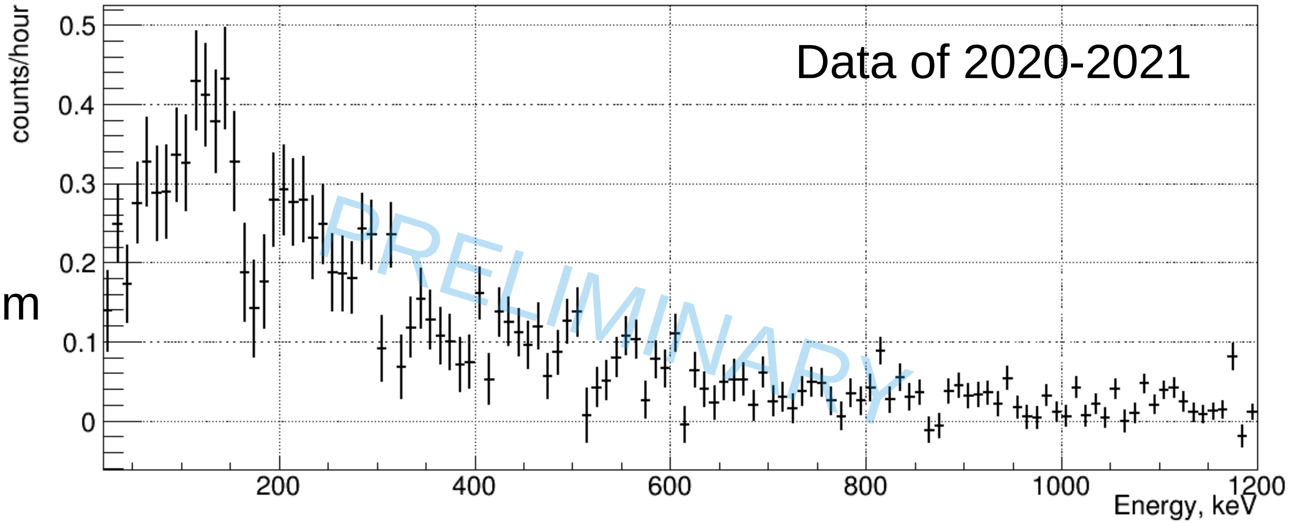
Plan:

1. Select periods with low Rn activity
2. Substract «early» and «late» periods

Residual carries info about the spectrum

What we get:

1. The diff. is up to 1200 keV
2. The diff. is similar to initial sprectrum



Candidates for the unknown BG component

http://nucleardata.nuclear.lu.se

Nuclide search

$T_{1/2}$(parent) ≥ 260 d; $T_{1/2}$(parent) ≤ 580 d;

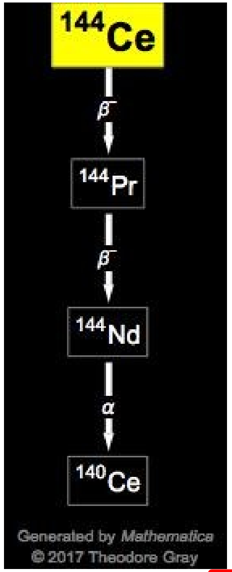
Nuclide	Z	N	Decay mode	Half life	E_x (keV)	Jπ	Abundance (%)
^{49}V	23	26	ε	330 d *15*	0	7/2-	
^{54}Mn	25	29	ε+β^+, β^-	312.3 d *4*	0	3+	
^{57}Co	27	30	ε	271.79 d *9*	0	7/2-	
^{68}Ge	32	36	ε	270.8 d *3*	0	0+	
^{106}Ru	44	62	β^-	373.59 d *15*	0	0+	
^{109}Cd	48	61	ε	462.6 d *4*	0	5/2+	
^{119m}Sn	50	69	IT	293.1 d *7*	89.531 *13*	11/2-	
^{143}Pm	61	82	ε+β^+	265 d *7*	0	5/2+	
^{144}Ce	58	86	β^-	284.893 d *8*	0	0+	
^{144}Pm	61	83	ε+β^+	363 d *14*	0	5-	
^{145}Sm	62	83	ε	340 d *3*	0	7/2-	
^{173}Lu	71	102	ε	1.37 y *1*	0	7/2+	
^{235}Np	93	142	ε, α	396.1 d *12*	0	5/2+	
^{248}Cf	98	150	α, SF	333.5 d *28*	0	0+	
^{249}Bk	97	152	β^-, α, SF	320 d *6*	0	7/2+	
^{252}Es	99	153	α, ε, β^-	471.7 d *19*	0	(5-)	
^{254}Es	99	155	α, ε, β^-, SF	275.7 d *5*	0	(7+)	

WANTED:

- E_{dep} > 1200 keV
- γ / β^-
- No extra lines
- Sane origin

Need to check the daughter-nuclei too!

A potential candidate: ^{144}Ce



$T_{1/2}$ = 285 d, E_β = 319 keV

$T_{1/2}$ = 17 m, E_β = 3 MeV

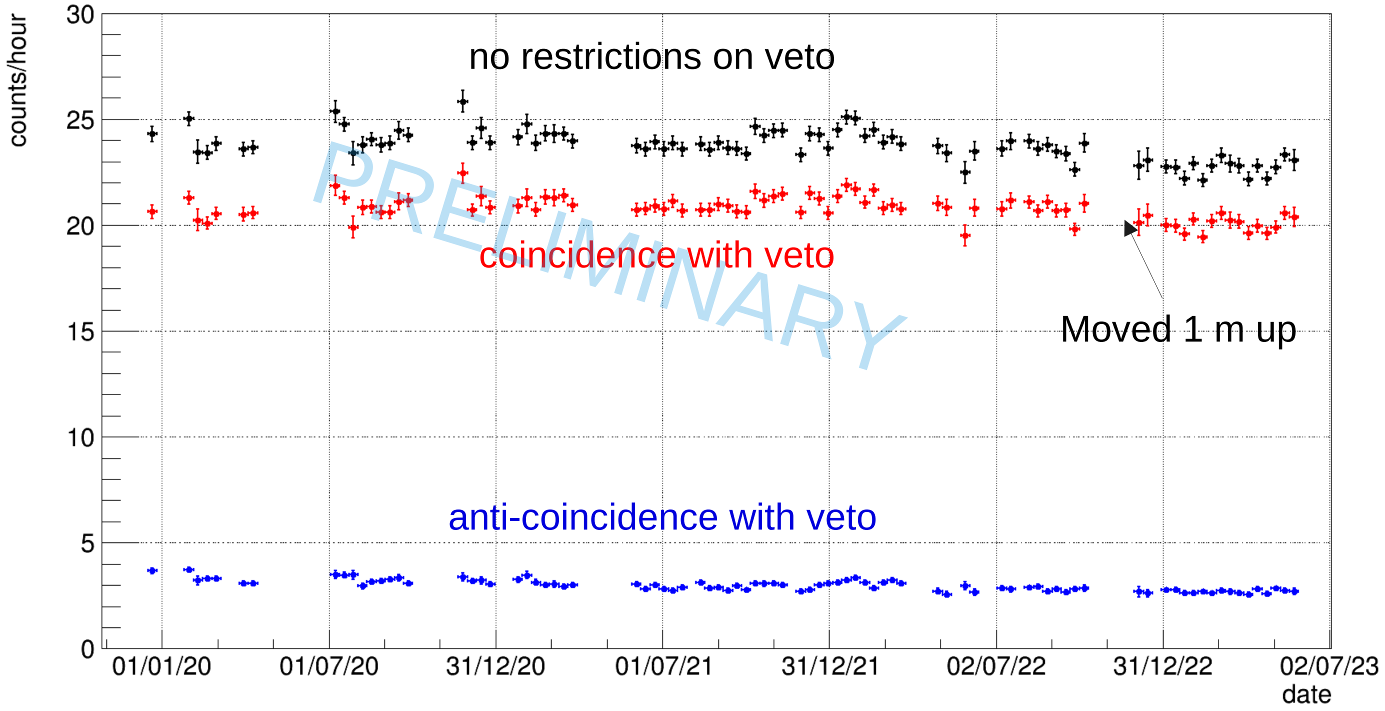
$T_{1/2}$ = 10^{15} y

Originates from the reactor fuel, thus should not be alone

Need a simulation to test

Other hypotheses

Can it be the degradation of the detector? - No



Can it be the change in the veto efficiency? - Maybe

No ~20% decrease in the rate associated with the μ veto

Conclusion

1. ^{222}Rn-related BG is observed, it can be taken into account

Empirical time profile from ^{214}Pb and ^{214}Bi

G4 sim under preparation for the energy profile

2. Plausible explanations for the BG decrease found, need a simulation

Time profile doesn't contradict the expo decay

The energy profile can be extracted from the data given the ^{222}Rn correction

Thank you for your attention!