MEASUREMENT OF RADON DECAYS WITH THE LVD-SETUP FOR NEUTRINO SEARCHING

N. Yu. Agafonova[1], E. A. Dobrynina[1], N. A. Filimonova[2]
(on behalf of the LVD Collaboration)

[1]Institute for Nuclear Research of RAS, Moscow, Russia; [2]Faculty of Physics and Energy Problems, Department of Fundamental Interactions and Cosmology, Moscow Institute of Physics and Technology (National Research University), Dolgoprudny

E-mail: agafonova@inr.ru

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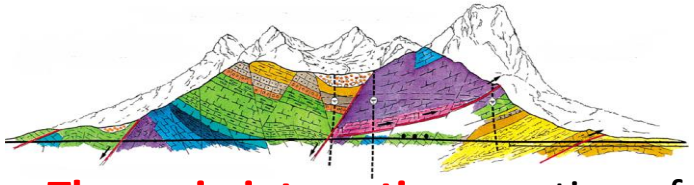
LVD – Large Volume Detector at underground Gran Sasso Lab, Italy

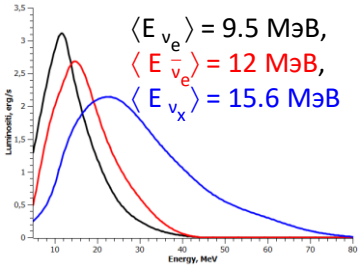
The main goal of LVD is searching for neutrino radiation from stellar core collapse

Depth of the underground laboratory ~ 3600m w.e.
Weakening of the muon flux 10^{-6}.

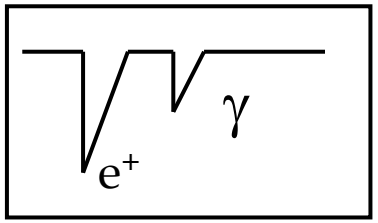
Length × Width × Height	22.7×13.2×10m
Mass C_nH_{2n}, Fe	1008 t, 1020 t
Number of counters	840
Threshold: ε_{HET}, ε_{LET}	5 MeV, 0.5 MeV



The main interaction reaction of electron antineutrinos is inverse beta decay (IBD), which creates two detectable signals: the first signal is caused by a positron (visible energy $E_{vis} = E\nu_e - 1.8$ MeV + 2 $m_e c^2$), followed by the capture of a neutron by protons or iron nuclei.

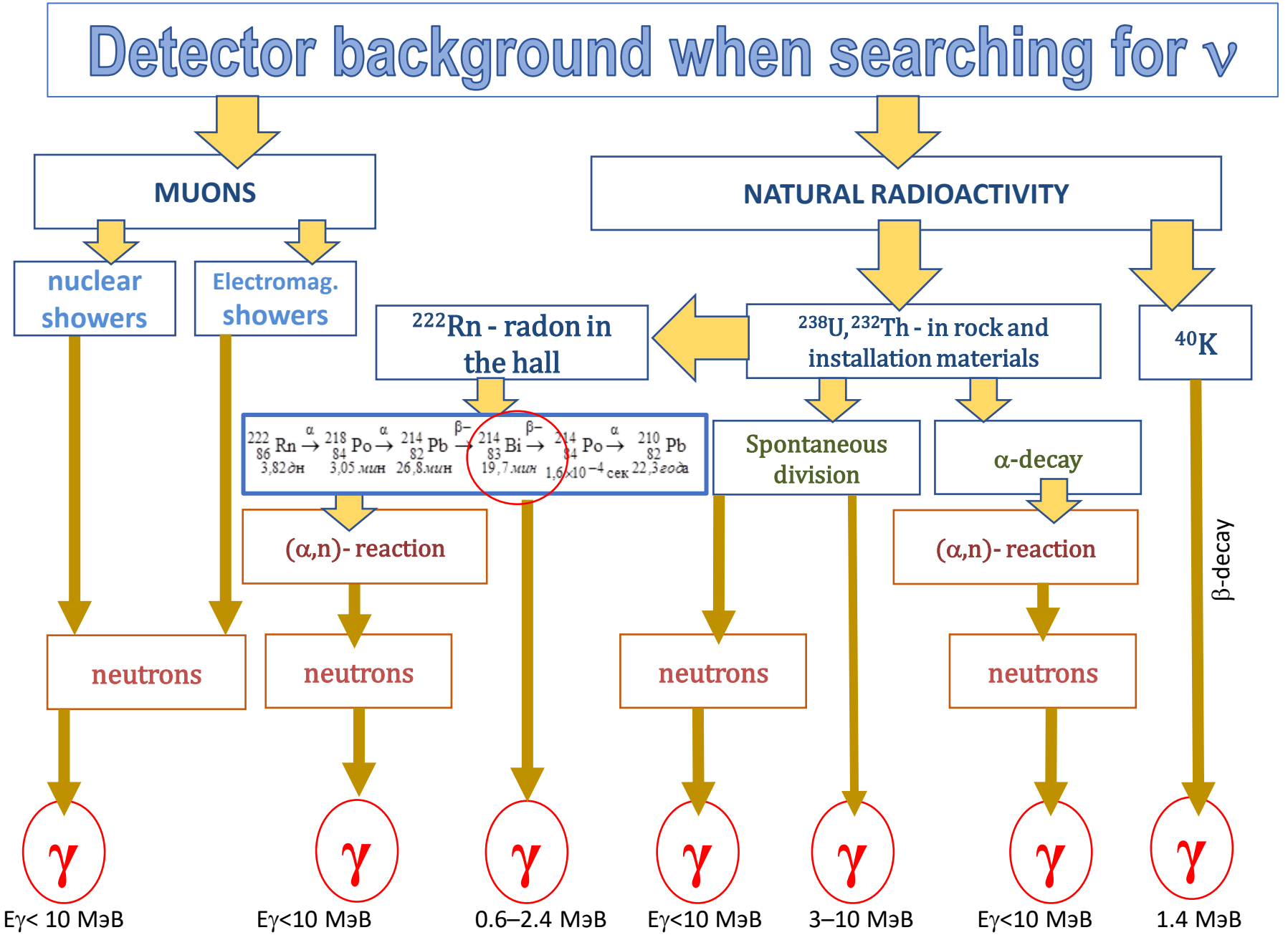


$$\tilde{\nu}_e + p \rightarrow e^+ + n$$



$$n + p \rightarrow d + \gamma$$
$$n + \mathrm{Fe} \rightarrow \mathrm{Fe} + \Sigma\gamma$$

$$\sigma_{\tilde{\nu}_e p} \sim 9.3 E_{e^+}^2 \cdot 10^{-44} \ \mathrm{cm}^{-2}$$


Detector background when searching for ν
MUONS
NATURAL RADIOACTIVITY
nuclear showers
Electromag. showers
222Rn - radon in the hall
238U, 232Th - in rock and installation materials
40K
222 86 Rn 3,82 дн → α 218 84 Po 3,05 мин → α 214 82 Pb 26,8 мин → β− 214 83 Bi 19,7 мин → β− 214 84 Po 1,6×10−4 сек → α 210 82 Pb 22,3 года
Spontaneous division
α-decay
(α,n)- reaction
(α,n)- reaction
β-decay
neutrons
neutrons
neutrons
neutrons
γ
γ
γ
γ
γ
γ
γ
Eγ< 10 МэВ
Eγ<10 МэВ
0.6–2.4 МэВ
Eγ<10 МэВ
3–10 МэВ
Eγ<10 МэВ
1.4 МэВ

Radon concentration in the underground laboratory

The LVD experiment hall has a volume of 24,000 m^3. When the gates are closed, the hall is airtight. Supply ventilation creates a slight overpressure in the hall. The temperature in hall A ranges from 17°C (near the floor in winter) to 22°C (under the ceiling in summer).

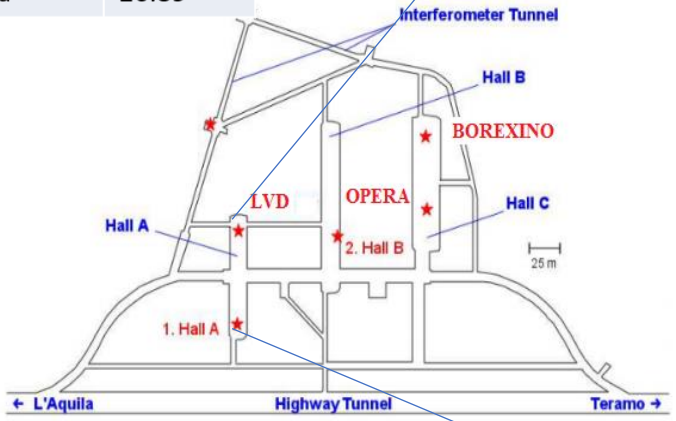
Average concentration ^{222}Rn	
Hall A	26 Bq/m^3
Hall B	43 Bq/m^3
Hall C	104 Bq/m^3

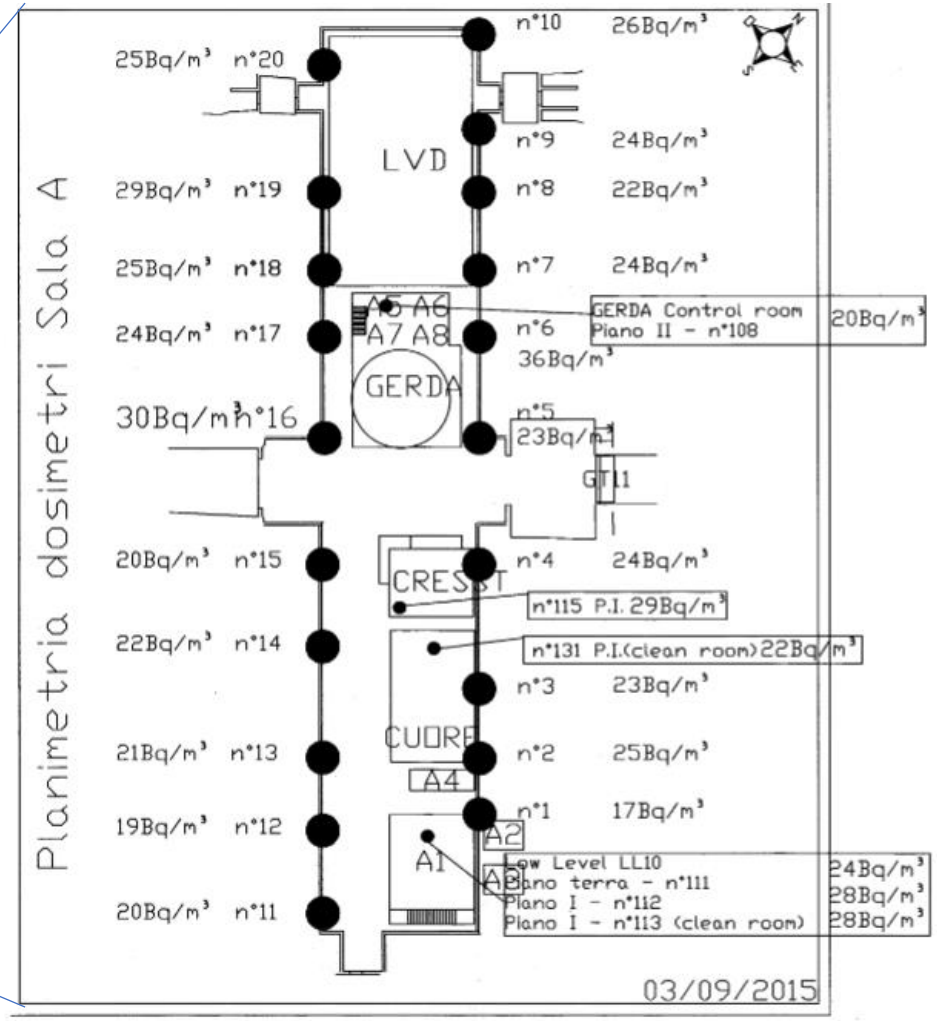
^{238}U and ^{232}Th activities in LNGS rock.

Hall	Activities (ppm)	
	^{238}U	^{232}Th
A	6.80 ± 0.67	2.167 ± 0.074
B	0.42 ± 0.10	0.062 ± 0.020
C	0.66 ± 0.14	0.066 ± 0.025

элемент	Масс.доля
H	0.03
C	12.17
O	50.77
Mg	8.32
Al	0.63
Si	1.05
K	0.1
Ca	26.89

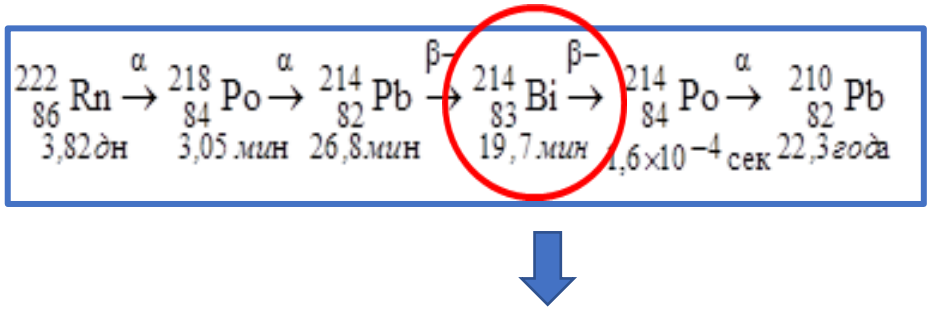
Gran Sasso rock contains mainly $CaCO_3$ and $MgCO_3$, density 2.71±0.05 g/cm^3.





Measurements of radon concentration in 2015

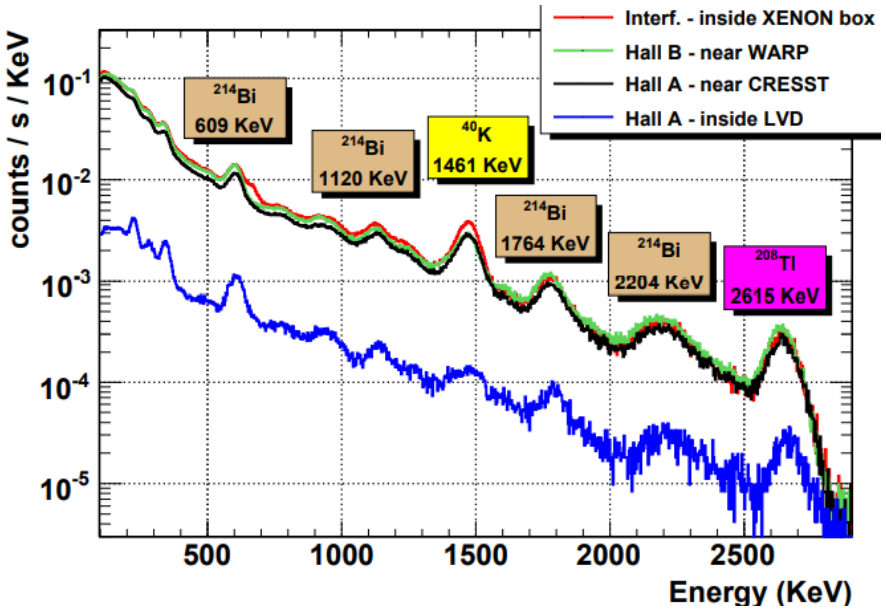
Event registration method in LVD from natural radioactivity

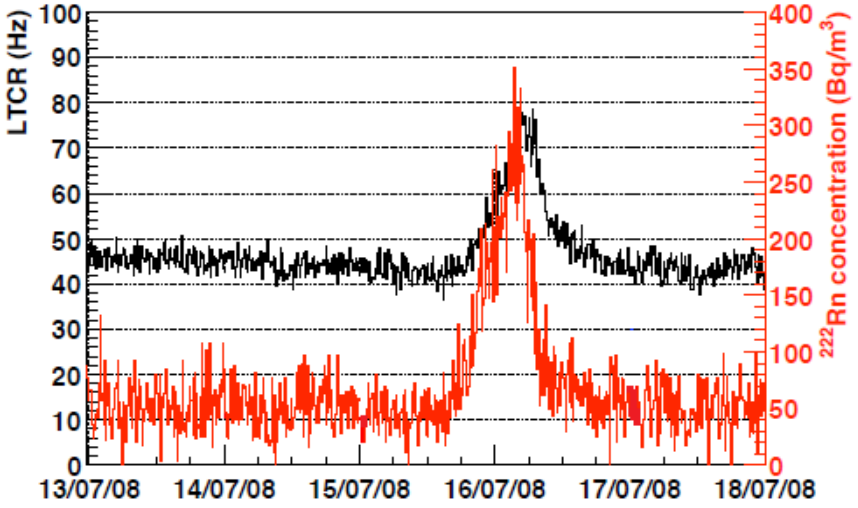


Monitoring of radon concentration is carried out by registering γ-quanta from the decay of daughter nuclei ^{222}Rn, the half-life of which is 3.8 days.

The LVD registration system contains a low-energy channel, the threshold of which is 0.5 MeV.

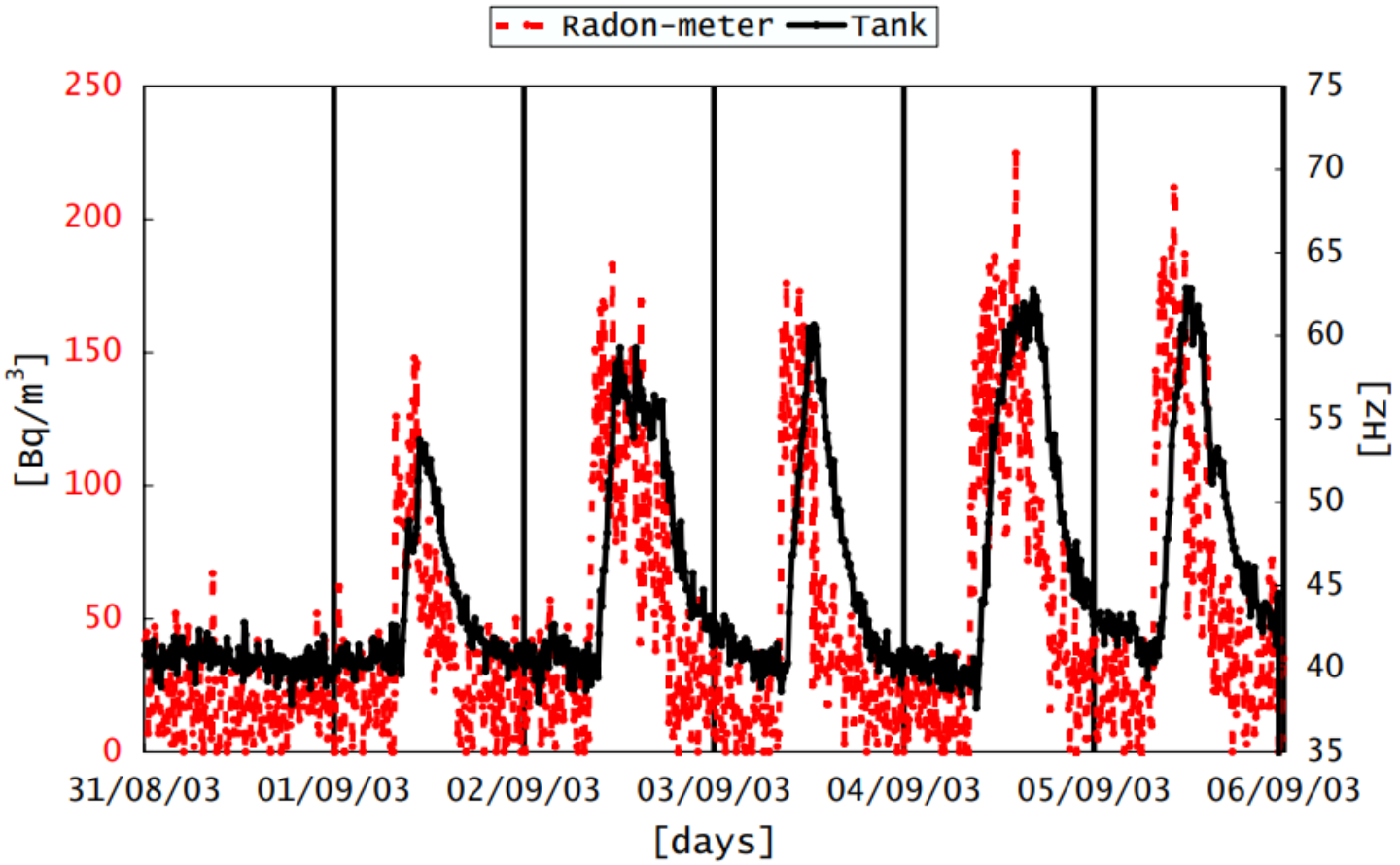
γ-quanta energy, MeV	Amount of gammas per 100 nuclei of ^{214}Bi
0,609	47
1,764	17
1,120	17
1,238	6
2,204	5
1,378	5
0,769	5
1,400	4
2,445	2





Low threshold LVD count rate correlated with radiometer readings (G. Bruno, PhD Thesis. 2012)

Comparison of LVD data with a radonometer

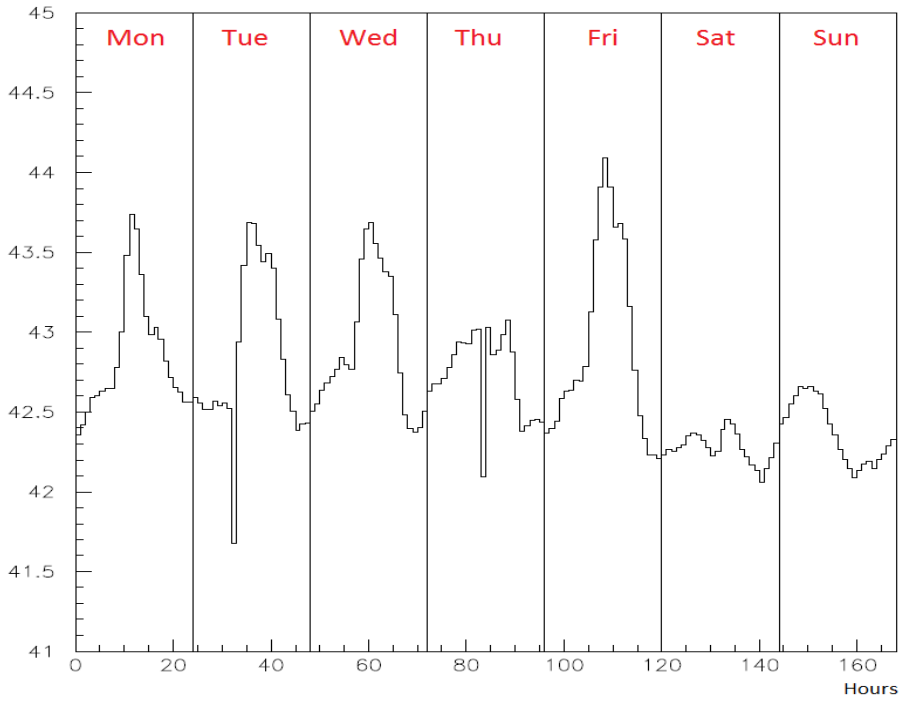


With the use of radonometer data, we can calibrate the LVD data in terms of radon activity.
A change of about 7 Bq/m3 causes an average 1 Hz change in the low energy LVD data.

The radonometer is located between two LVD towers (the ionization chamber of the radonometer measures alpha particles with an air flow of 1.0 l/min).
There is a strong correlation between radonometer data and LVD data; thus, the modulation can be explained as a change in the radon concentration **due to a change in the pressure** in the hall (for example, due to the opening and closing of the doors of the experimental hall).
There is a delay between the LVD data and the radonometer data. The maximum correlation is obtained when the radonometer data is delayed by about two hours relative to the LVD data.

G Bruno and H Menghetti (LVD Collaboration) Journal of Physics: Conference Series 39 (2006) 278–280

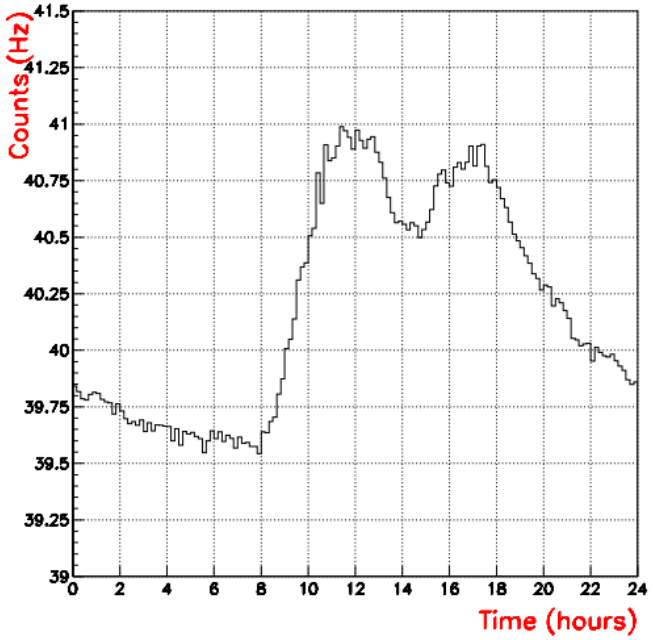
Diurnal-, weekly- Variations



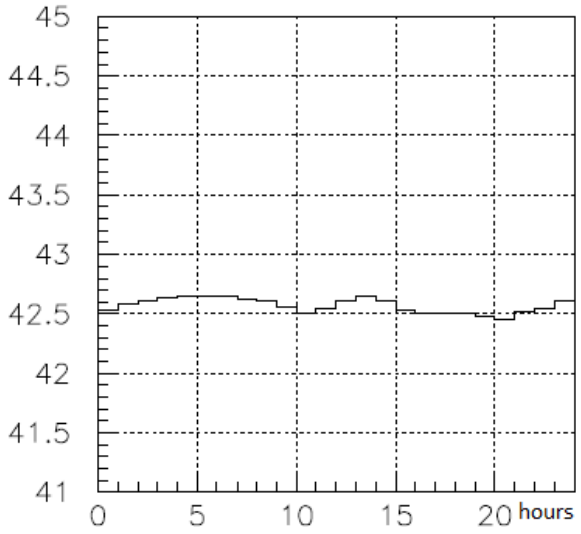
LVD count rate variations are related to radon variations in the underground hall.

Opening and closing the gate to the hall where the unit is located: supply ventilation creates an excess of pressure, when the gate is opened, the pressure drops and radon begins to intensively escape from the walls.

The passage of cars through the transport tunnel: causes vibration of the ground, as a result of which the release of radon into the atmosphere of the hall increases.



working days

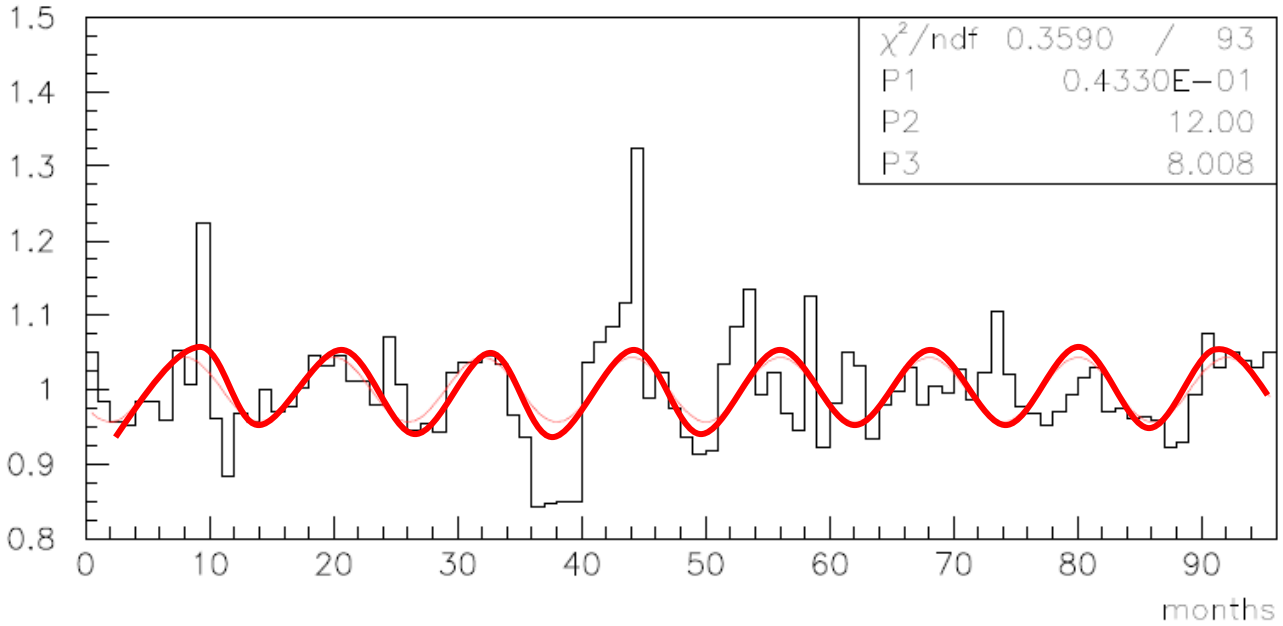


weekend

N.Yu Agafonova et al. "Study of the Low-Energy Background Variations in the LVD Underground Experiment" Bulletin of the Russian Academy of Sciences: Physics, 2019, Vol. 83, No. 5, pp. 614–616

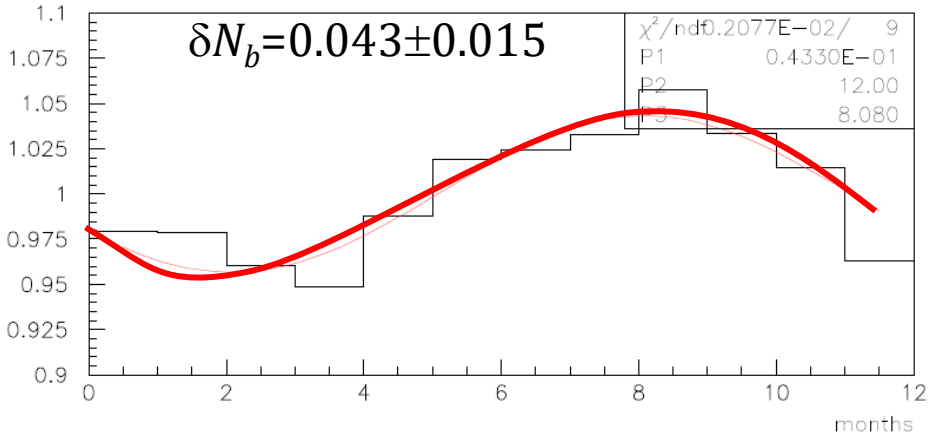
Long term variations: annual modulations

Variations are due to seasonal fluctuations in radon concentration and additional release of radon from groundwater.



$$f(t) = 1 + \delta N_b \cdot \cos\left(\frac{2\pi}{T}(t - \varphi)\right)$$

Variations in radon concentration during the year, obtained by the epoch folding method.

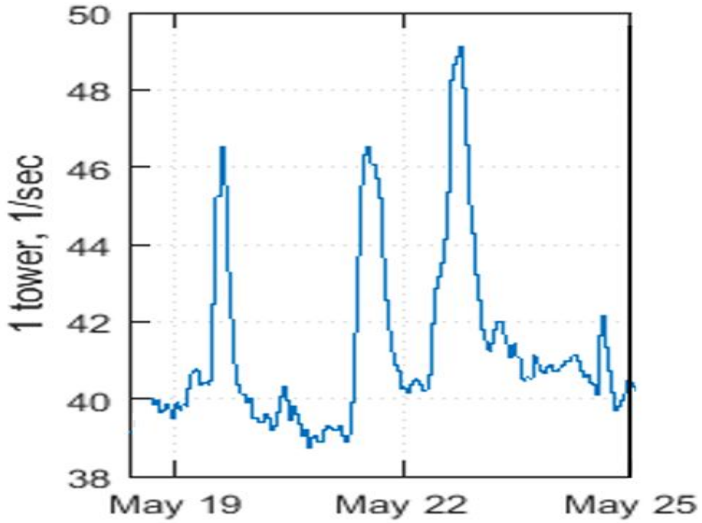


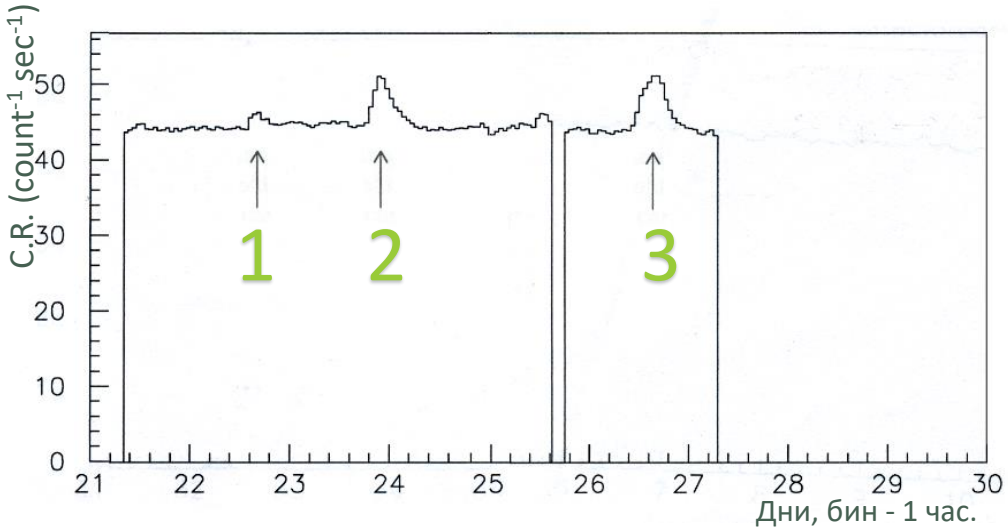
Measurements with gate opening in the hall

"Radon peak" refers to the rapid change in the concentration of radon in the underground room where the LVD unit is located.

The decline in radon concentration in the hall :

$C_{Rn}(t)=C_0\exp(-t/\tau_{вент})$, где $\tau_{вент}=V_{зала}/F=2.75$ часа, $V_{зала}=22000$ м^3 , F=8000 м^3·час$^{-1}$





We opened the gates in the experimental hall for a fixed time:

1) 0.5 hours
2) 3 hours
3) 6 hours.

Were determined experimentally:

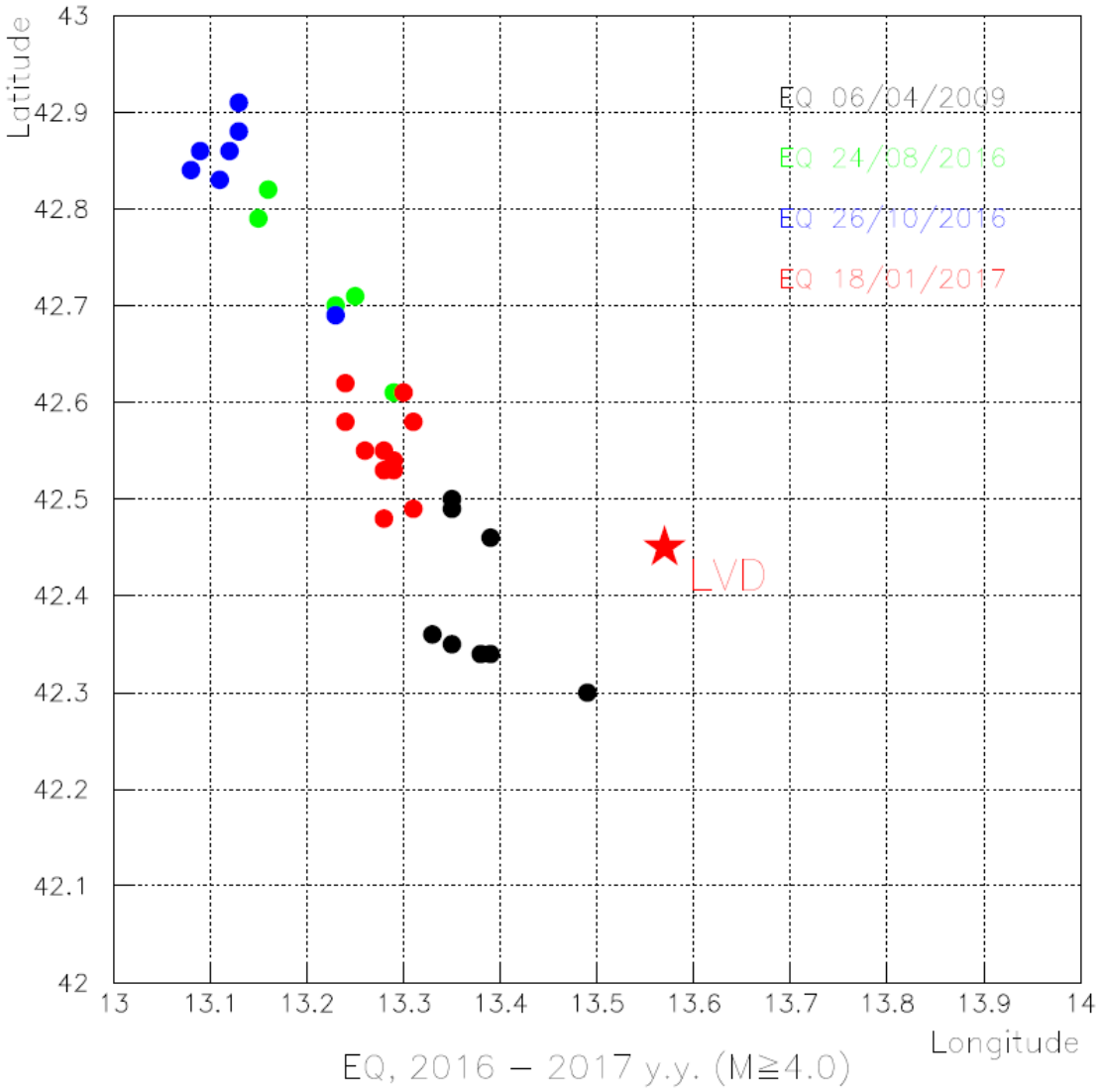
- the duration of the rise of the peaks,
- the time of mixing the air in the hall
- the time to return to the equilibrium state.

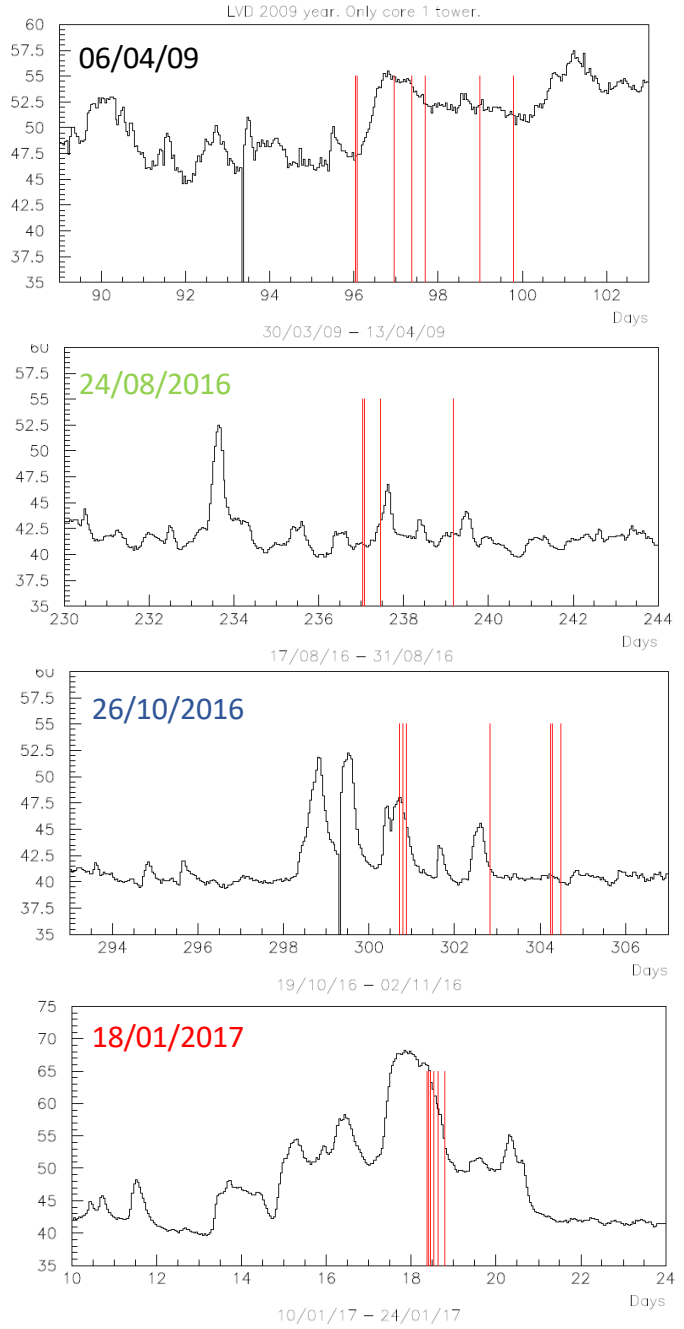
The rise time of the value of C_{Rn} in this case was: 3 hours - in the first two cases and 6 hours - in the last. From this we can conclude that **the time of mixing** the air in the hall is about 3 hours**.**

Conclusion : The shape of the peak is due to the injection of radon into the atmosphere of the hall and its blowing out by ventilation. Parameters for changing the value are determined C_{Rn} : **rise time** (front) is from 3 to 10 hours and exponential decay is up to ~14 hours with an exponent $\tau \approx 3$ hour.

Powerful earthquakes in Italy

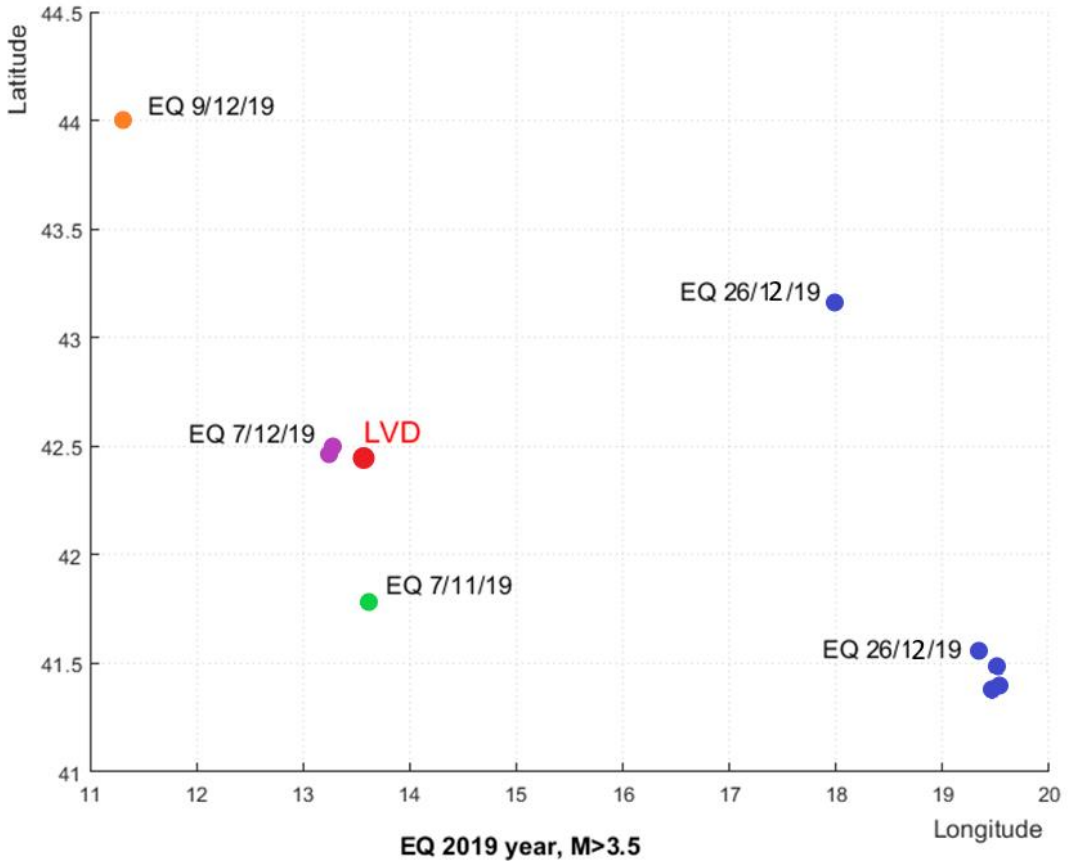
Coordinates of epicenters of powerful seismic events relative to the location of the LVD setup.

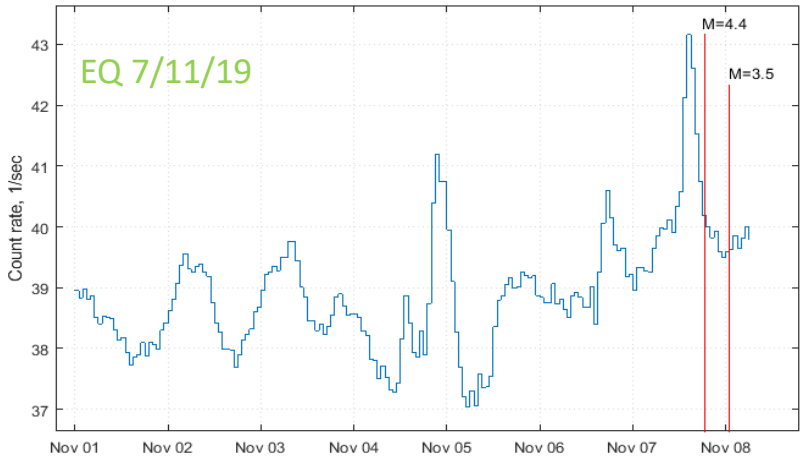


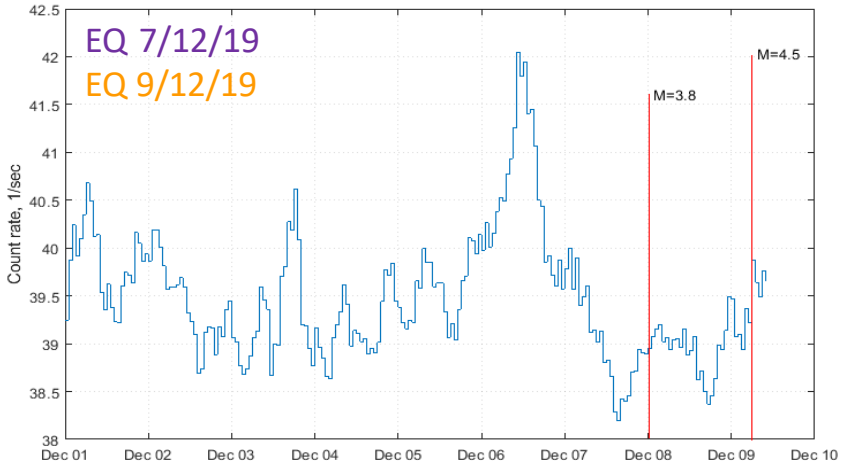


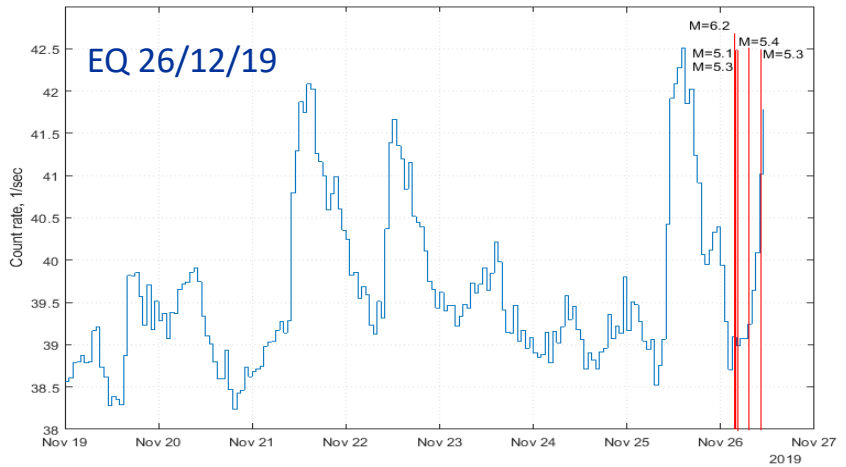
Earthquake 2019

The figure shows the coordinates of the epicenters of the above considered seismic events relative to the location of the LVD setup.





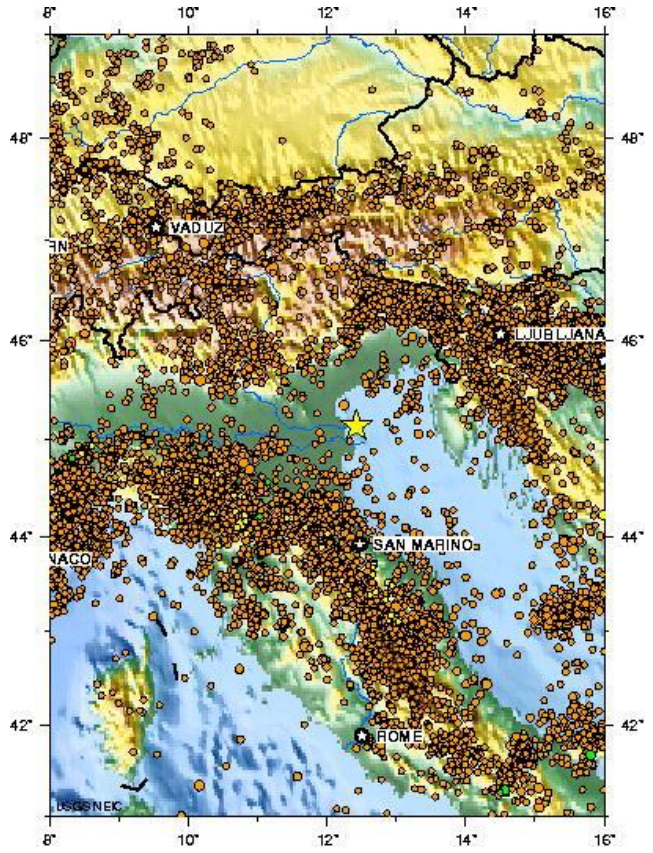




Н. Ю. Агафонова и др. ИЗВЕСТИЯ РАН. СЕРИЯ ФИЗИЧЕСКАЯ, 2021, том 85, № 11, с. 1661–1665

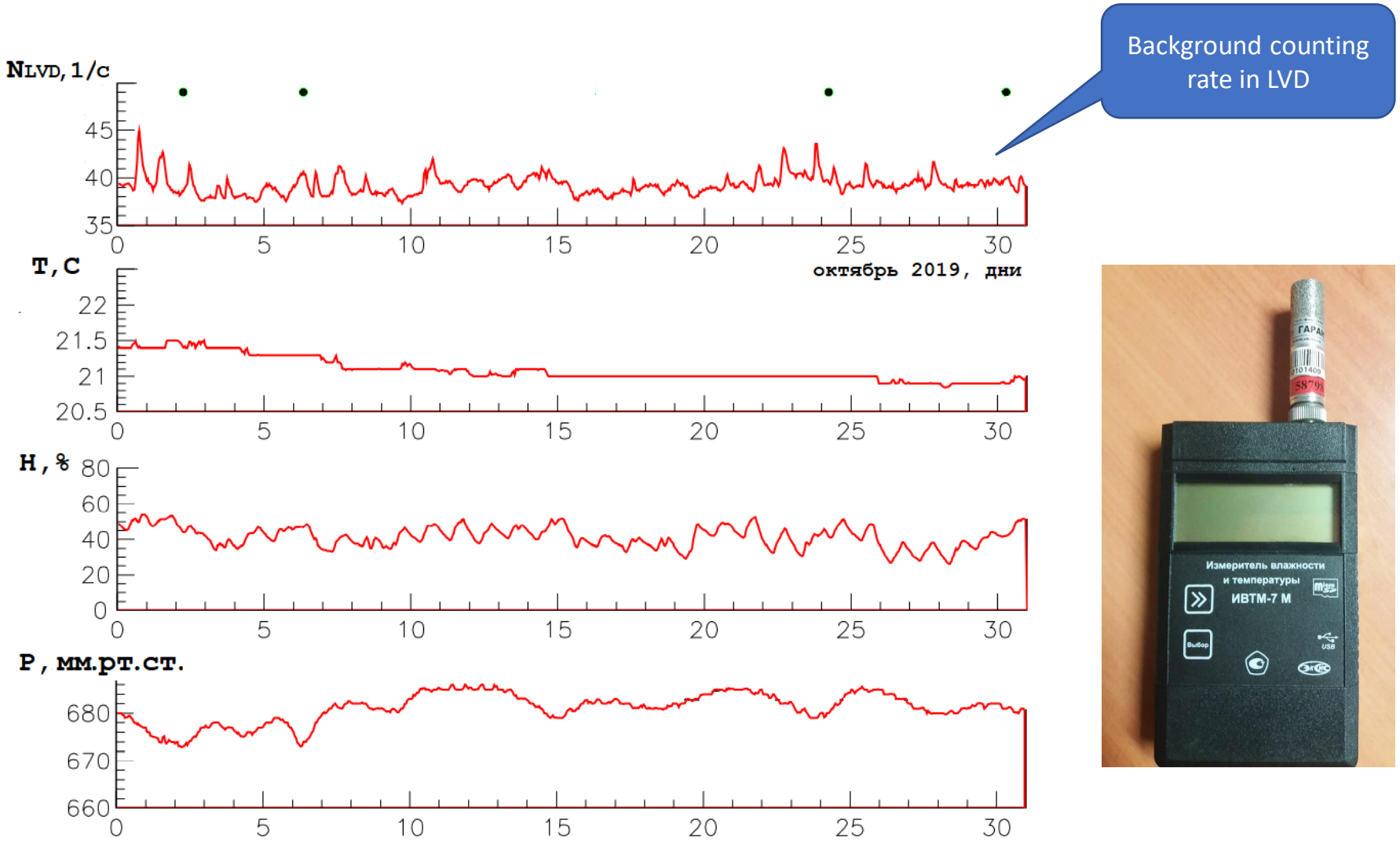
Factors affecting the concentration of radon in an underground laboratory.

1. **Opening and closing the gate to the hall where the detector is located:** supply ventilation creates an excess of pressure, when the gate is opened, the pressure drops and radon begins to intensively escape from the walls.
2. **The passage of cars through the transport tunnel:** causes vibration of the ground, as a result of which the release of radon into the atmosphere of the hall increases.
3. **Seasonal variations in radon concentration:** in summer, the water saturation of the soil is higher, which leads to an accelerated transport of radon.
4. **Seismic activity**: when the earth's crust is deformed, the number of microcracks increases, stress arises and vibration of the soil increases, which leads to a significant increase in the concentration of radon.
5. **Tidal forces associated with the lunar cycle:** should probably enhance the release of radon.

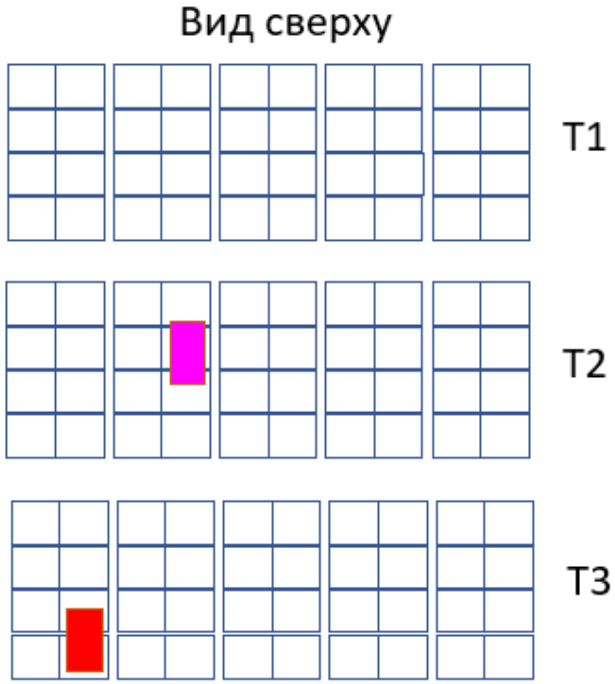


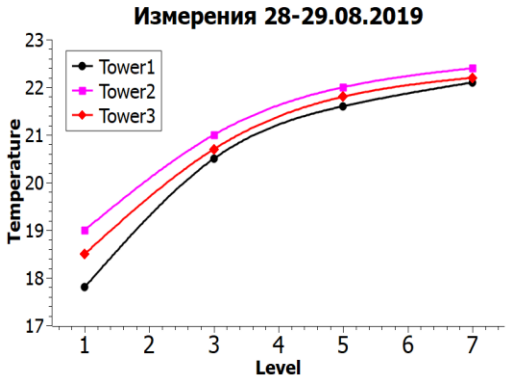
The end

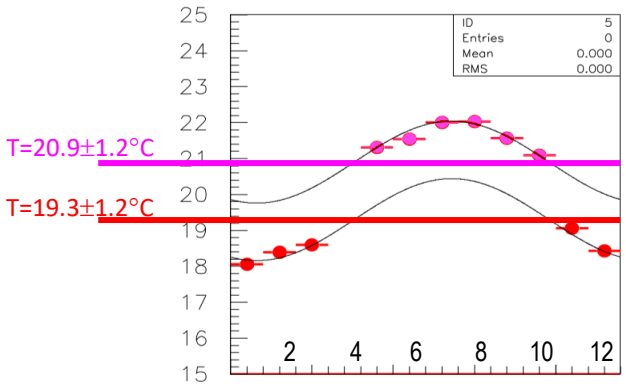
Temperature, humidity and pressure measurements



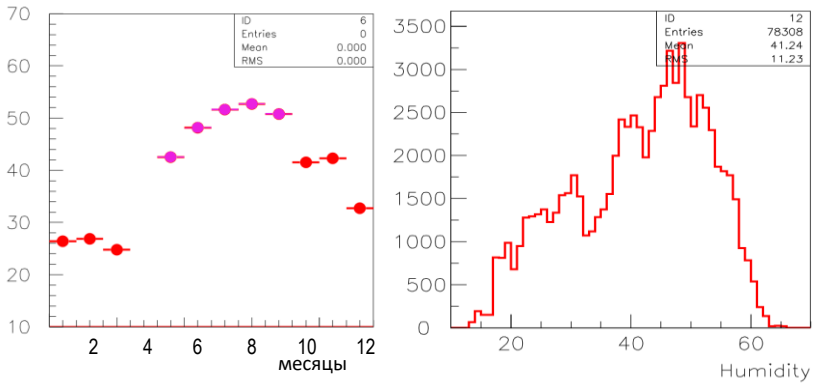
Измерения Температуры, Влажности, Давления в зале



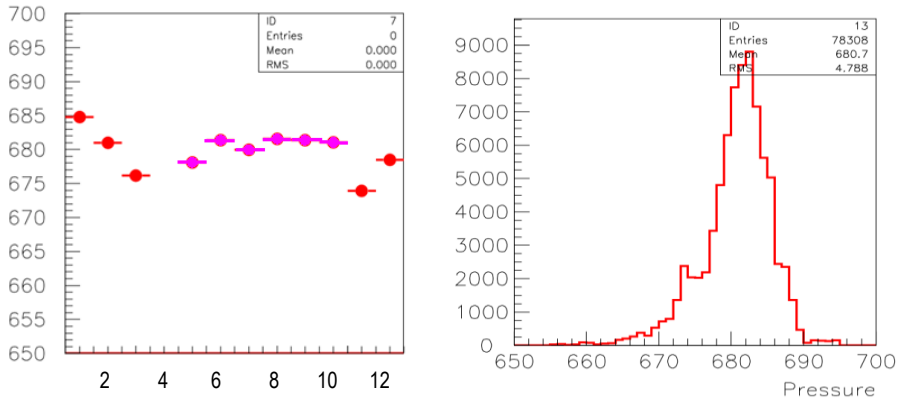




Слева (а) - зависимость температуры от высоты (L=1 – нижний уровень, L=7 - верхний), справа (б) – измерения средней температуры за месяц с мая 2019 по март 2020 г., верхняя кривая – для положения ТГ на счетчике N2456, нижняя – на N3512



Распределение измерений влажности в зале



Распределение измерений давления в зале.