# Decay rate measurements with a $^{137}Cs$ radioisotope source at Jánossy Underground Research Laboratory
(Wigner RCP, Csillebérc, Hungary)

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# Introduction

- Elementary particles that can emit either $W^+$ or $W^-$ boson (force carriers of the weak interaction) can induce transitions of the down (d) and up (u) quarks.
- Both the $d + W^+ \rightarrow u$ and the $u + W^- \rightarrow d$ process is possible. The atomic nuclei of the chemical elements contain u and d quarks.
- Thus, changes of the intensities of the fields of $W^+$ or $W^-$ boson emitting particles (e.g. neutrinos) might modulate the stochastic spontaneous decay and the half life ($T_{1/2}$) of radioactive atomic nuclei.
- Neutrinos are produced in several man made, geological, atmospheric, solar, astrophysical and cosmological processes.
- According to estimations (e.g. Athar, 2022) the estimated flux of the neutrinos on earth from the Big Bang is $\approx 10^{22}$ $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ in the $10^{-8}$ - $10^{-6}$ eV energy region
- the flux of neutrinos produced in the core of Sun is $\approx 10^{11}$ $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ in the $10^{10}$ – $10^{12}$ eV energy region.
- The solar neutrino flux can vary according to the eccentricity of the orbit of Earth and the solar flair activity.
- (Athar, 2022)      M. Sajjad Athar, A. Fatima, S. K. Singh, Neutrinos and their interactions with matter, https://doi.org/10.48550/arXiv.2206.13792

(Pomme, 2022) S. Pommé, H. Stroh, T. Altzitzoglou, J. Paepen, R. Van Ammel, K. Kossert, O. Nähle, J.D. Keightley, K.M. Ferreira, L. Verheyen, M. Bruggeman, Is decay constant?, Applied Radiation and Isotopes 134 (2018) 6–12.

# Introduction

**Measurements at low background sites**

- Therefore, mainly at low background counting sites, several long-term counting studies have been started to study and interpret any deviation from the well-known exponential law of the radioactive decay.
- Several publications on the results of the measurements have been available in the literature. A recent paper (Pomme, 2022), citing several publications, presents a summary of the results obtained for $^{3}H$, $^{14}C$, $^{22}Na$, $^{54}Mn$, $^{65}Zn$, $^{90}Sr$, $^{109}Cd$, $^{134}Cs$, $^{152}Eu$, $^{209}Cd$, $^{226}Ra$ and $^{241}Am$.

**Measurements at Wigner Research Centre for Physics (Budapest, Hungary)**

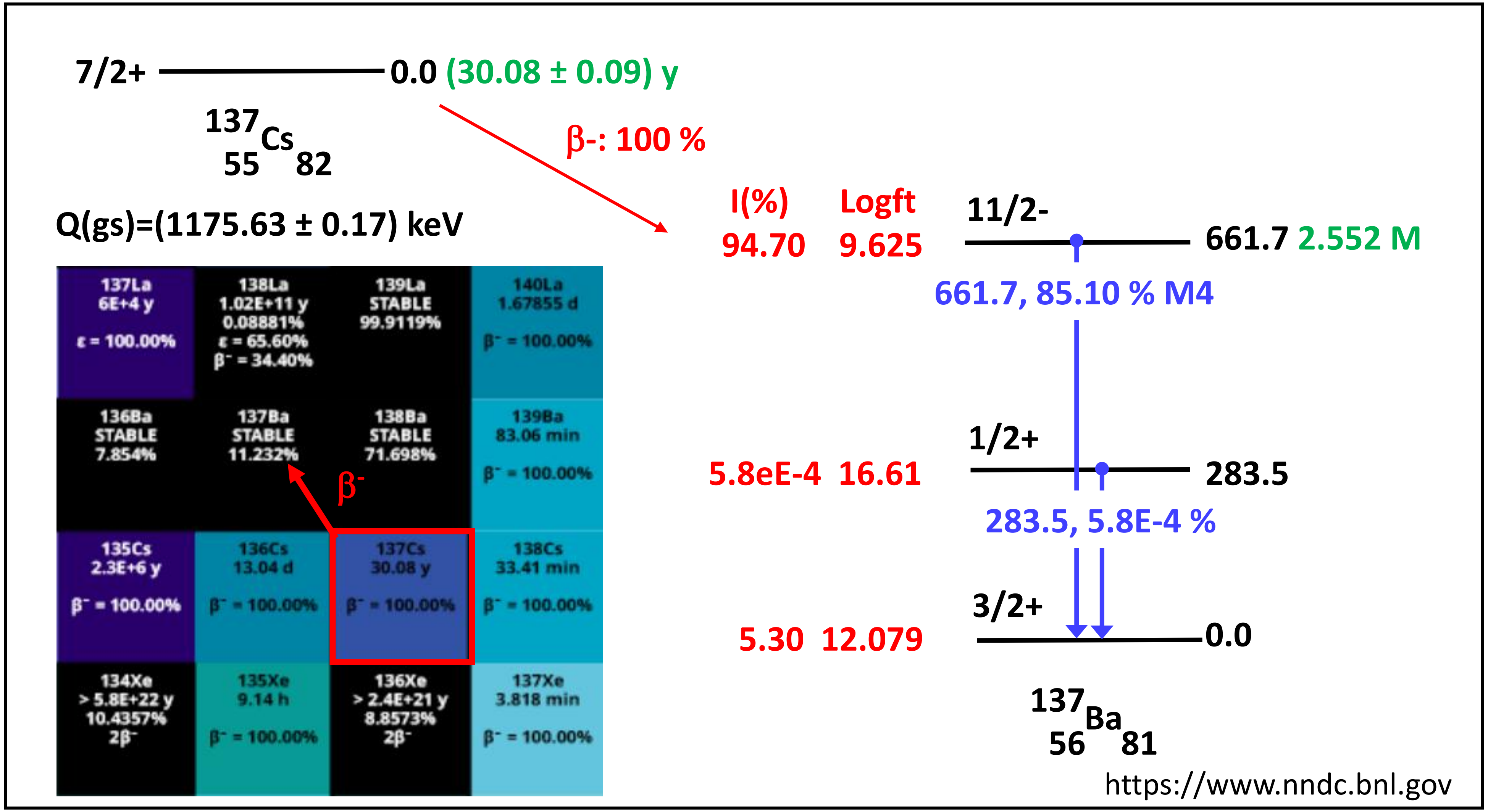
- The measurements were carried at a HPGe detector at a low background counting site located 30 m underground in the Vesztergombi High Energy Laboratory in the Janossy Underground Research Laboratory (JURLab, KFKI Campus, Csillebérc, Budapest, Hungary).
- Mai goal: investigating the effect of environmental and seasonal changes on the background spectra
- Current measurement campaign: Oct 2022 – Dec 2023 (data of 15 months will be collected
- **In this work: presenting preliminary results for 137Cs.**
- Nucleon synthesis measurements in weak decay channels with low radiation background:

    Szegedi TN, Kiss GG, Mohr P, Psaltis A, Jacobi M, Barnafoldi GG, Szucs T, Gyurky G, Arcones A,

    Activation thick target yield measurement of 100Mo(α,n)103Ru for studying the weak r-process nucleosynthesis

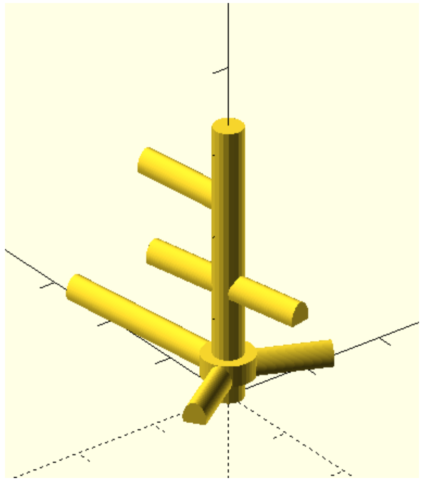
    PHYSICAL REVIEW C 104 : 3 Paper: 035804 , 7 p. (2021)

# The decay scheme of $^{137}Cs$



# Jánossy Underground Research Laboratory

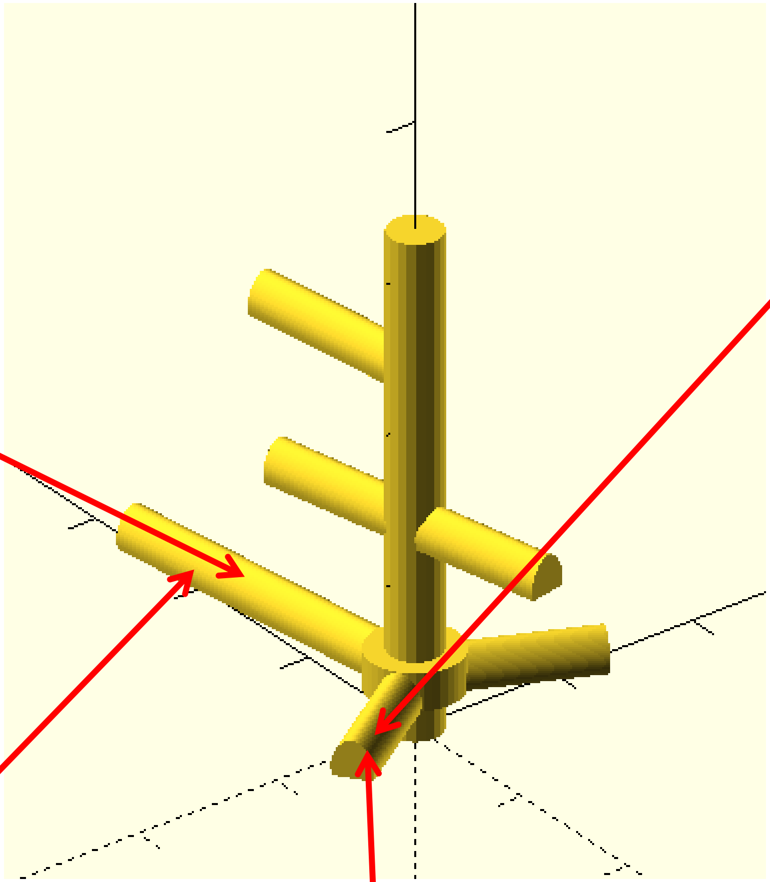
- 30m below the ground in Dachstein-type limestone
- The useful area of the lab is 150 sqm on 3 levels
  - 20 sqm at level -1,
  - 2x20 sqm at level -2
  - 2x20 sqm + 50sqm at level -3.
- 40 cm thick walls made from concrete for nuclear reactors
- air conditioning, uninterruptible power supply, internet and service/rescue telephone availability
- the site ideal for measurements that need low cosmic background
- also appropriate for other measurements that require stable temperature and low environmental- and seismic noise level
- physical environment is monitored by temperature-, pressure- and humidity sensors together with a seismometer and an infrasound microphone.
- full CAD model & density map is awailable



# Ongoing Experiments

Muon tomography

Re-measurement of the Eötvös Experiment



High Purity Germanium (HPGe) Radiation Detector

Infrasound and seismology

Radon detection

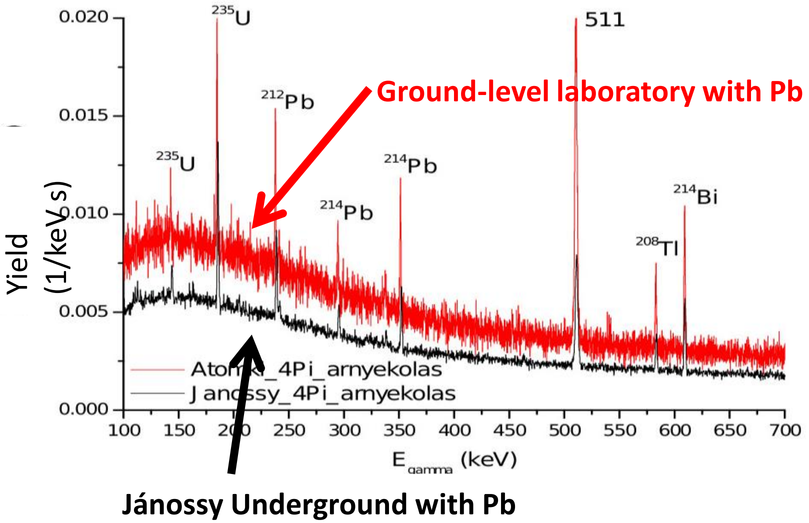
# Low-background Radiation Measurements

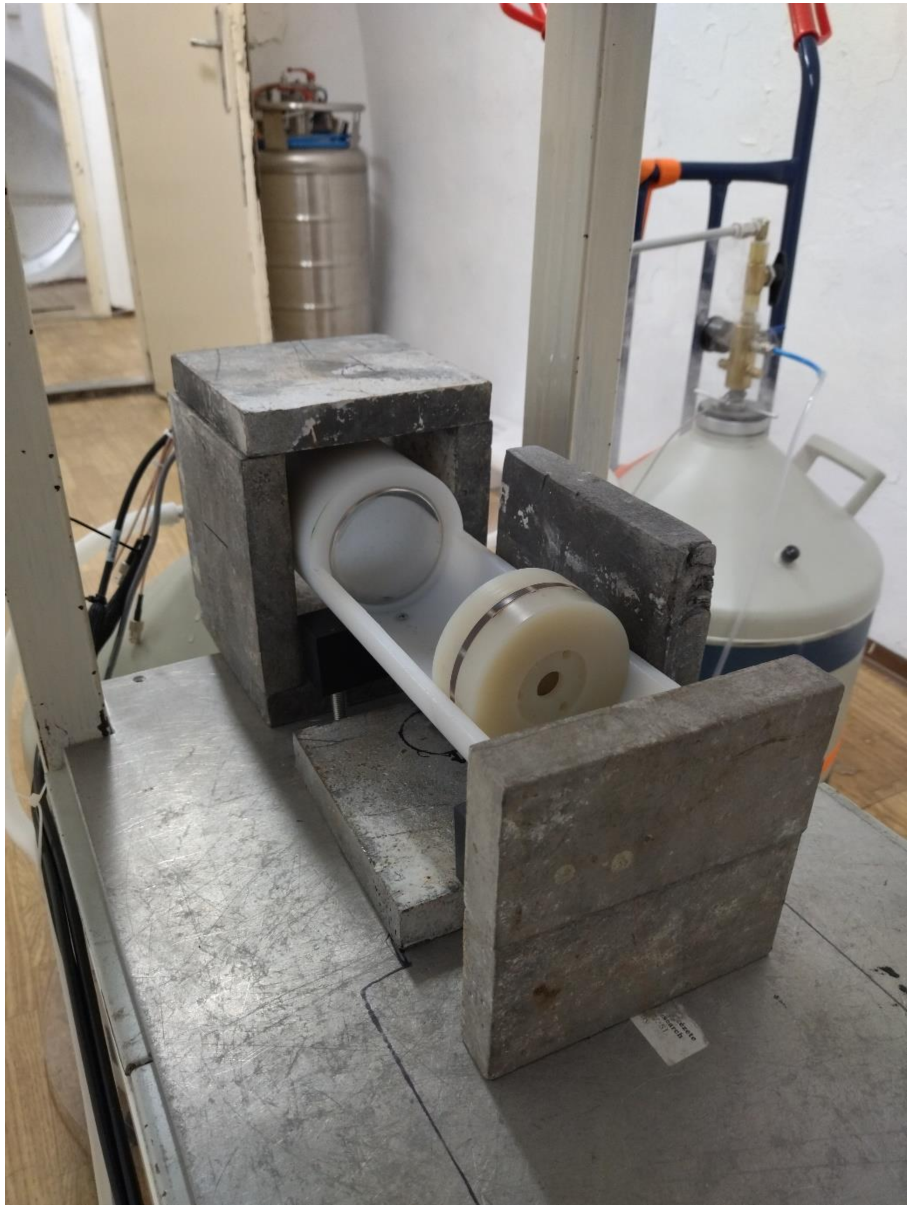
**High-purity Germanium (HPGe) detector**

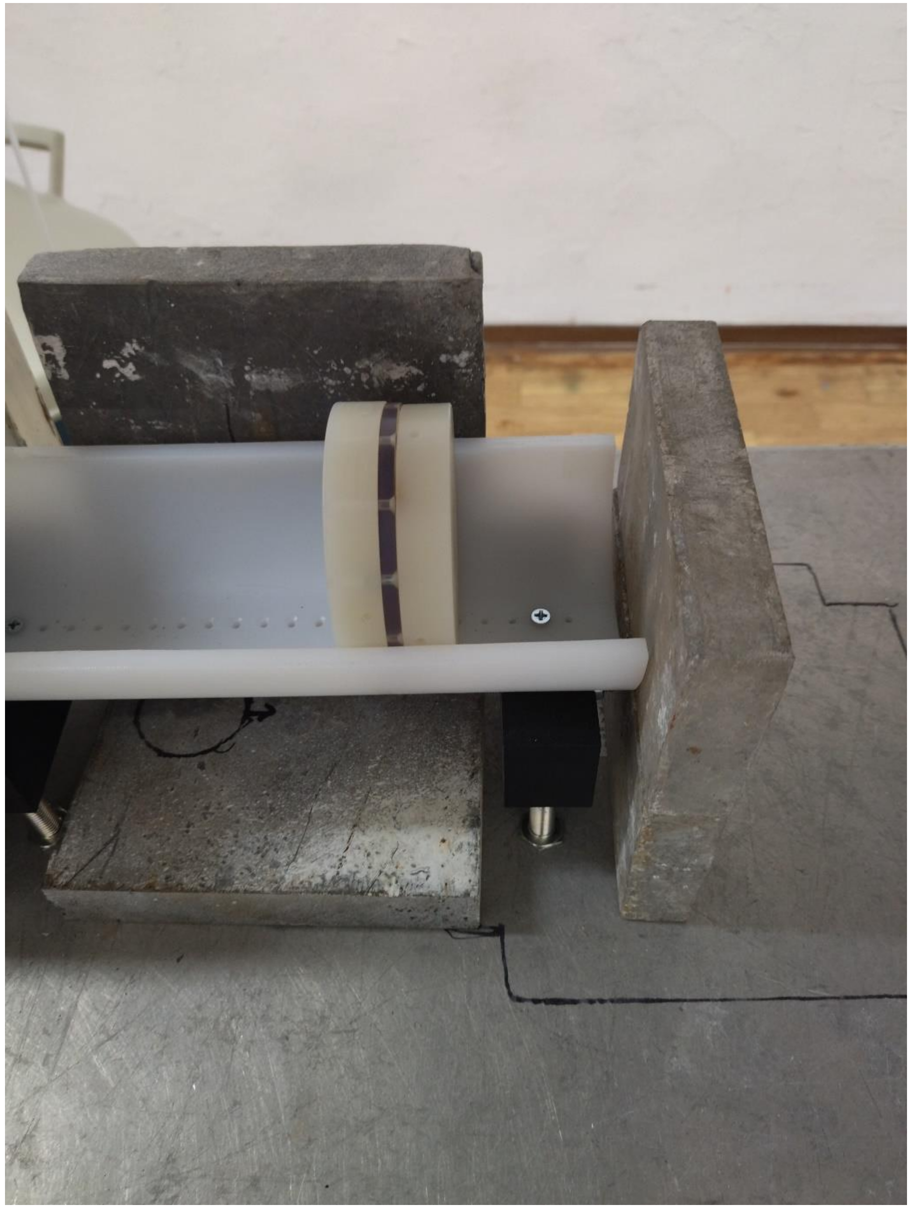
- Nucleon synthesis measurements in weak decay channels with low radiation background
- Measurement of radiation decay anomaly
- Radon measurements with stable and variable environmental conditions
- Remote-controlled, automatized long-range measurements (Canberra + Lynx DSP)

**Setup at JURL**

- a high-purity Ge detector of relative efficiency of ≈ 40% at 1332 keV (model GC4018 from Canberra) and a LYNX-MCA digital signal analyzer
- The analyzer is controlled remotely via its HTTP interface



# Data processing

**Calibration**

- Gamma spectra were collected into histograms of 32768 bins
- Energy calibration was linear: $E = A + Bk$, where $k$ is the $k$-th channel of the DAC (0 ≤ k ≤ 32767).
- Coefficients $A$= 0.0676 keV, $\mathrm{B}$=0.1765 keVwere calibrated to the $^{214}$P b and $^{40}$K peaks at 351.9321 and 1460.802 keV, respectively, which are clearly visible in the background
- Calibration was performed just once, in March 2022. Thereafter, A and B were kept fixed, i.e., no re-calibration was done mid-measurement.

**Backgroud substraction**

- Background in the measured raw spectrum was estimated by fitting a quadratic polynomial of energy to the sidebands [650, 657] keV and [669, 674] keV of the peak.
- After background subtraction, the area (total count) under the peak was determined using a Gaussian fit in the full [650, 674] keV range.

**Dead-time correction**

- We did not have a dedicated setup for dead time measurement, so we relied on the live time estimates stored by the analyzer in the CNF output: $\Delta t_{live} = \Delta t_{nominal} - \Delta t_{dead}$
- Extracted background-subtracted peak areas were corrected for dead time by up-scaling to the nominal one-hour measurement duration by a factor $\Delta t_{nominal}/\Delta t_{dead}$

# Analysis

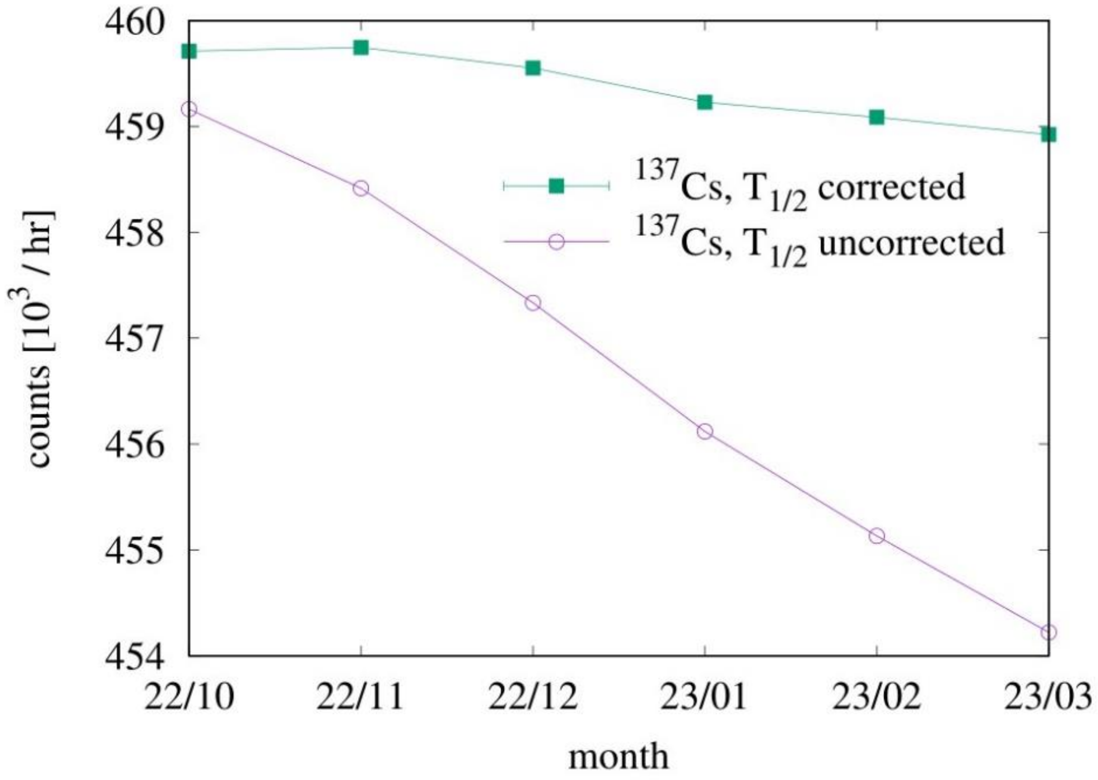
- First, each hourly dataset was analyzed separately.
- Then background-subtracted and dead-time corrected peak areas are tallied and then averaged as counts per hour for each month of the measurement: Oct 2022 to Mar 2023.
- A gradual decreasing trend is manifest, as would be expected from a slow exponential decay of the source activity. The halflife of $^{137}Cs$ is $T_{1/2}$= 30.05 ± 0.08 yr so in half a year the source should weaken by ≈ 1.1%.
- During a time interval [t, t + Δt] the average source activity, relative to the activity at time $t_0$ is

$$R(t, \Delta t|t_0) = \frac{1}{e^{-\lambda t_0}}\left(\frac{1}{\Delta t}\int_t^{t+\Delta t} dt' e^{-\lambda t'}\right) = e^{-\lambda(t-t_0)}\frac{1-e^{-\lambda\Delta t}}{\lambda\Delta t},$$

where $\lambda \equiv \frac{ln2}{T_{1/2}}$ is the decay constant of $^{137}Cs$.

- The measured activity in each mini-run was scaled back, i.e., the extracted peak areas, to a common reference time $t_0$ by dividing by $R(t_{nominal}, \Delta t|t_0)$, where $t_0$ = Oct 1, 2022, 0:00:00

# First results




- After correction, $\sim 0.2\%$ decrease is still visible
- This indicates that background subtraction and/or the gaussian fit of the peaks are not accurate enough