NEUTRINO 2020

A SEARCH FOR RESONANT ABSORPTION OF SOLAR AXIONS BY ^{83}KR

A. DERBIN, I. DRACHNEV, A. GANGAPSHEV, YU. GAVRILYUK, V. KAZALOV, V. KOBYCHEV, V. KUZMINOV,
V. MURATOVA, S. PANASENKO, S. RATKEVICH, D. SEMENOV, D. TEKUEVA, E. UNZHAKOV

INSTITUTE FOR NUCLEAR RESEARCH (RAS),
PETERSBURG NUCLEAR PHYSICS INSTITUTE (NRC "KURCHATOV INSTITUTE")

INTRODUCTION

Axion — a hypothetical **pseudoscalar boson**, which was originally introduced in order to solve a longstanding **problem of CP-nonviolation** in strong interactions. A **spontaneous breaking** of new **chiral symmetry** proposed by R. Peccei and H. Quinn at some energy f_A solves the strong CP-problem; at the same time this breaking gives rise to a new boson (i. e. axion) due to **Nambu-Goldstone mechanism**.

The **axion interactions** with ordinary matter are described in terms of **effective coupling constants**: $g_{A\gamma}$ (photons), g_{Ae} (leptons), g_{AN} (nucleons). Axion mass m_A and coupling constants g_{AX} appear to be **inversely proportional** to symmetry breaking scale f_A: $m_A \sim 1/f_A$

Initial assumptions estimated f_A to be of electroweak scale, but a series of experiments quickly **excluded** this "**standard axion**" model.

Soon, new **modified theoretical models** emerged, allowing f_A to be **arbitrary large**, suppressing the interactions of axion with ordinary matter and reducing its expected mass — **"invisible" axion**. Naturally, these features made the "invisible" axion a viable **dark matter candidate**, creating additional motivation for its experimental discovery.

SOLAR AXIONS AND HOW TO DETECT THEM?

Stars could be intense **sources of axions**, thanks to a number of processes:

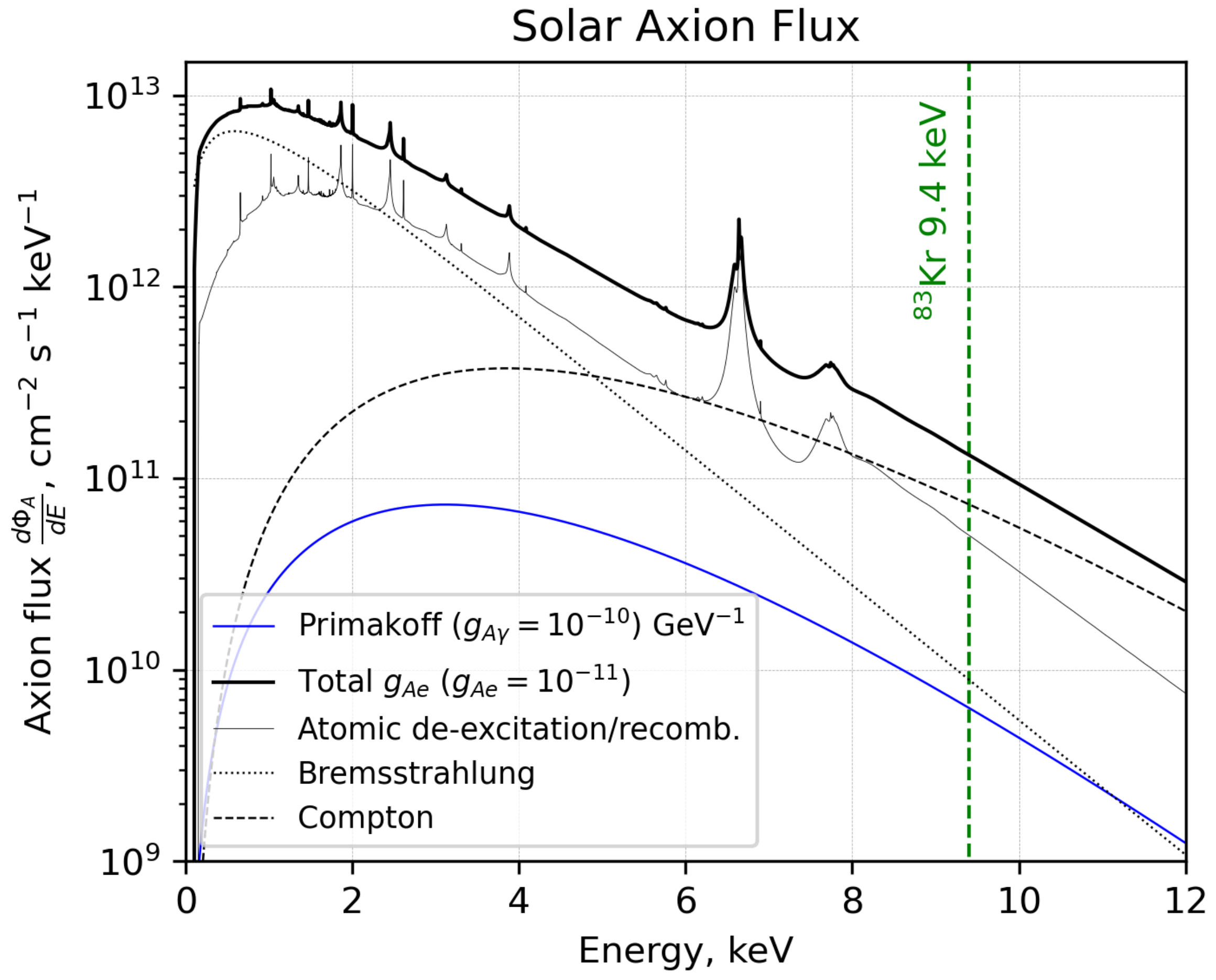
- Nuclear reactions of pp-chain (g_{AN})
- Thermal excitation of nuclei (g_{AN})
- Primakoff effect ($g_{A\gamma}$)
- Axion bremsstrahlung (g_{Ae})
- Compton-like process (g_{Ae})
- Atomic de-excitation/recombination (g_{Ae})

Due to the Sun's proximity to Earth the stellar **axion flux** at the Earth's surface will be **dominated by solar axions**.

Axions could be **detected** through reaction of **resonant absorption** by atomic nucleus (g_{AN}). The **relaxation** of excited nuclei would produce **γ-quanta and electrons**, detectable by conventional means.

Particular isotopes (^{57}Fe, ^{169}Tm, ^{83}Kr) possess **low-energy nuclear transitions** of M1-type, which allow for testing for axion masses in $1 - 10$ keV range, consistent with the expected solar flux.

For our experiment **^{83}Kr target** with 9.4 keV transition was used.

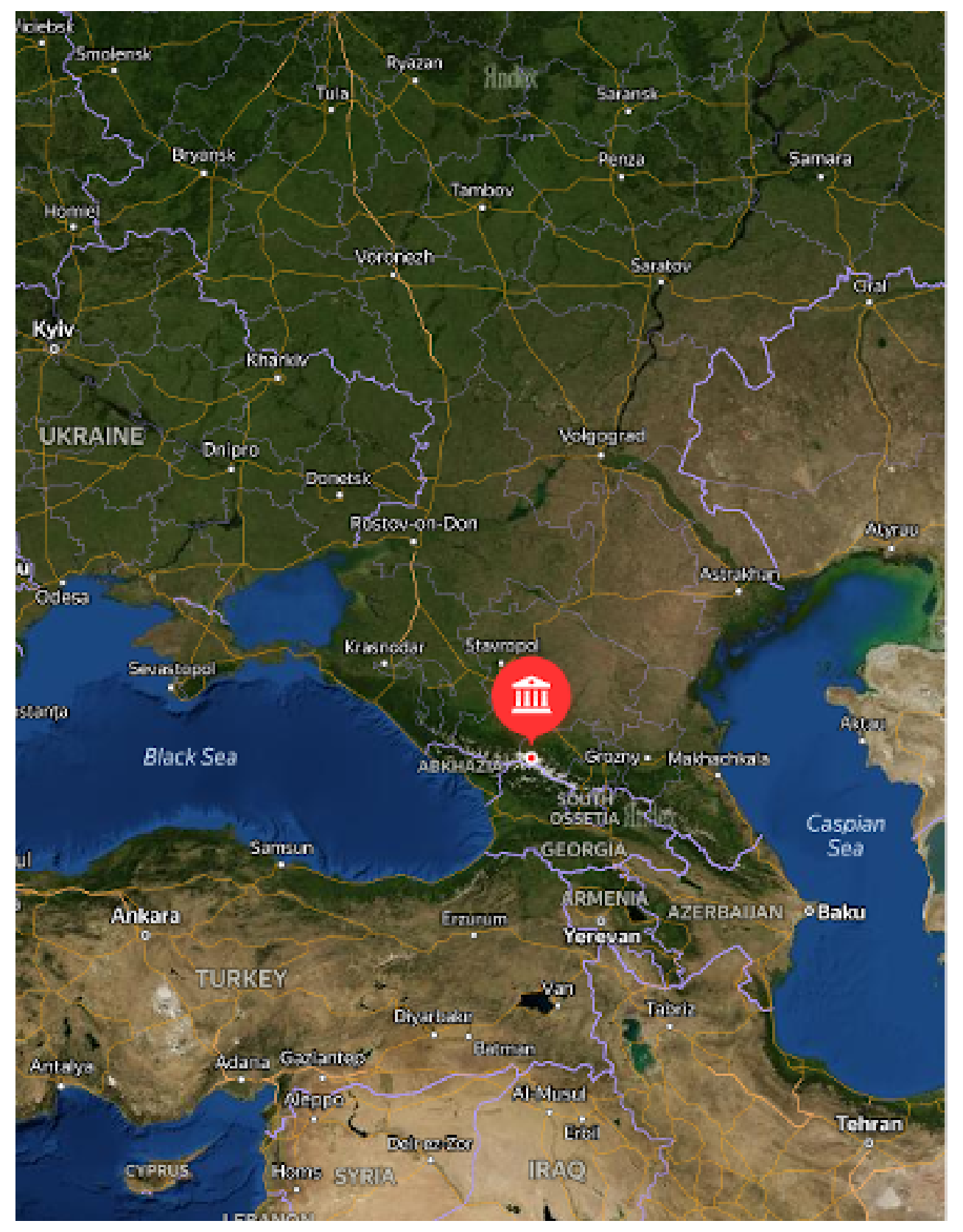


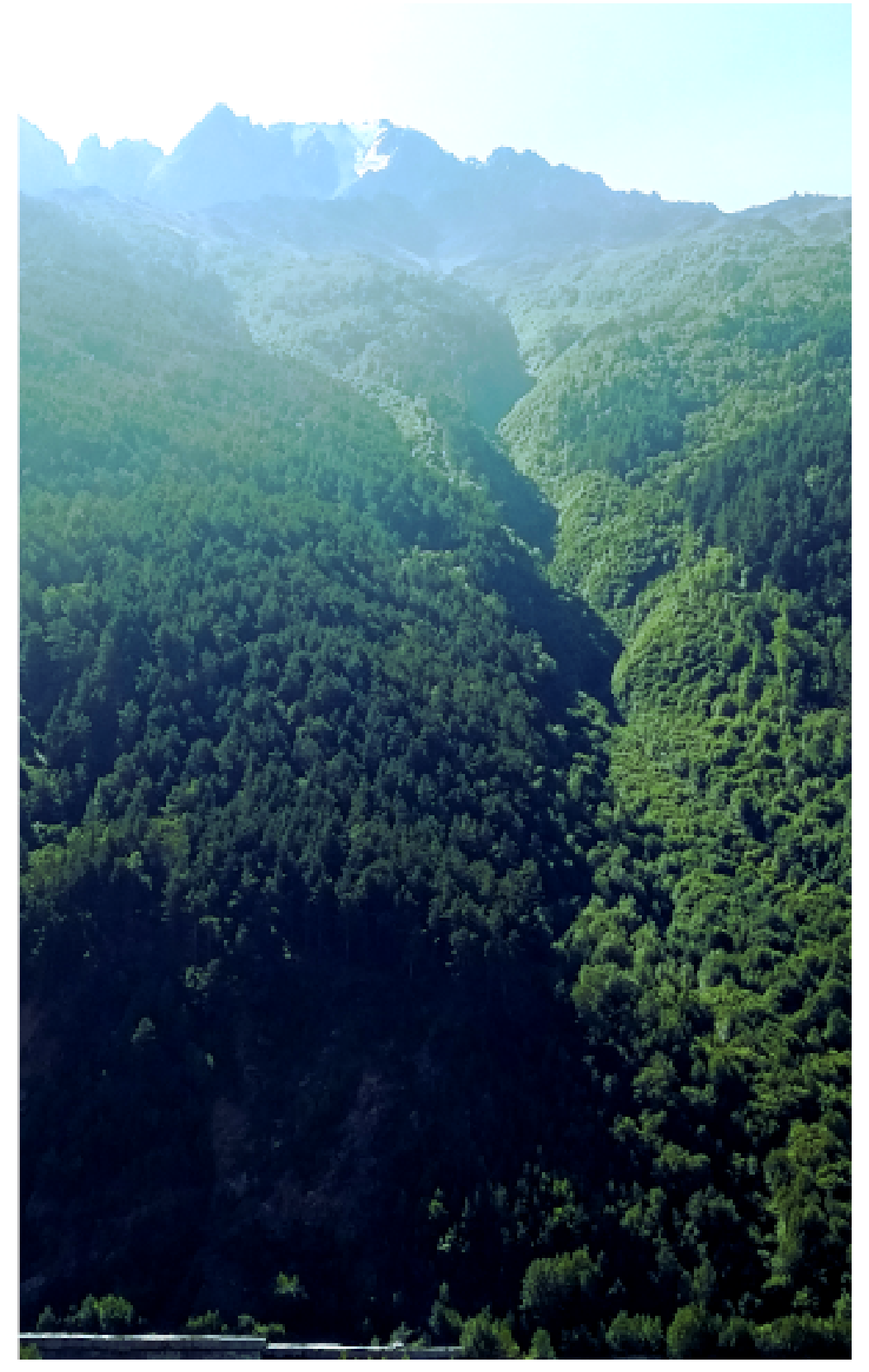
REFERENCES

[1] Y. M. Gavrilyuk, A. N. Gangapshev, A. V. Derbin, et al. New constraints on the axion-photon coupling constant for solar axions. *JETP Lett.*, 107:589–584, 2018.

[2] A. H. Abdelhameed, S. V. Bakhlanov, P. Bauer, et al. New limits on the resonant absorption of solar axions obtained with a 169tm-containing cryogenic detector. *Eur. Phys. J. C*, 80:376, 2020.

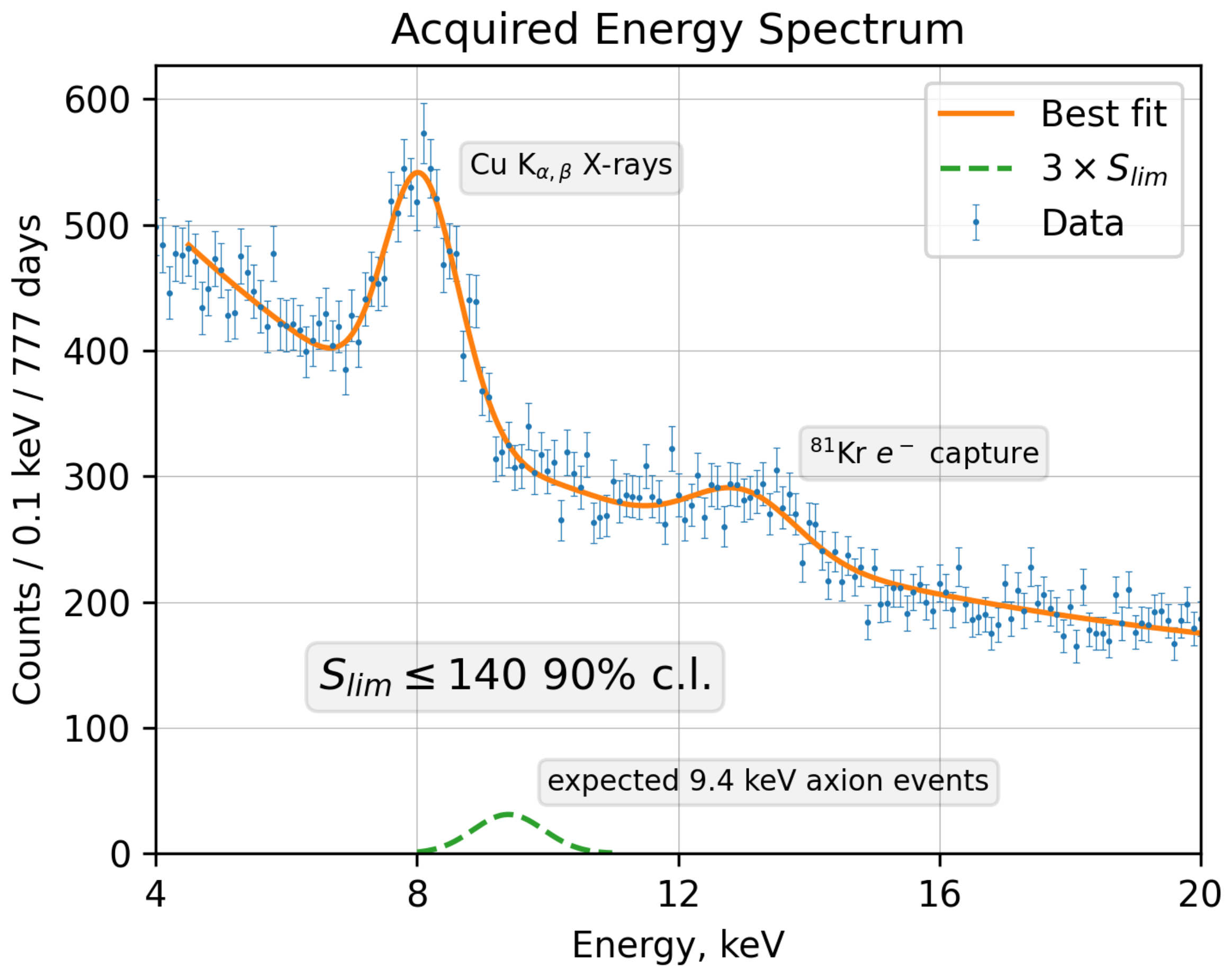
BAKSAN UNDERGROUND FACILITY AND EXPERIMENTAL SETUP





The experimental setup was located in the **low-background** laboratory of **Baksan underground facility** (4900 m. w. e). The large gas **proportional counter** consisted of **copper cylinder** ($l = 735$ mm, $\varnothing = 137 - 150$ mm) and was filled with **57** g of ^{83}Kr (**99.9**% enrichment).

The energy spectrum was acquired over **777** days of live-time. Since there was **no visible peak** in the region of interest, the **upper limit** on the amount of axion events was found to be $S_{lim} \leq \mathbf{140}$ at **90**% c. l.



ACHIEVED LIMITS ON AXION COUPLINGS