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Production of ^{83}Rb for calibration sources for dark matter and neutrino mass experiments

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Short-lived isomer ^{83m}Kr with its discrete electron spectrum has ideal properties to be used in the crucial role of calibration source in low energy experiments like KATRIN or XENON. To ensure smooth long-term operation of these experiments, reliable routines for production of ^{83}Rb, which decays to ^{83m}Kr, have to be developed. We describe the methods developed at the Nuclear Physics Institute of the Czech Academy of Sciences at Rez, where ^{83}Rb sources are created for KATRIN predominantly via the reaction ^{84}Kr(p,2n)^{83}Rb by colliding accelerated protons with a target filled with natural krypton gas.

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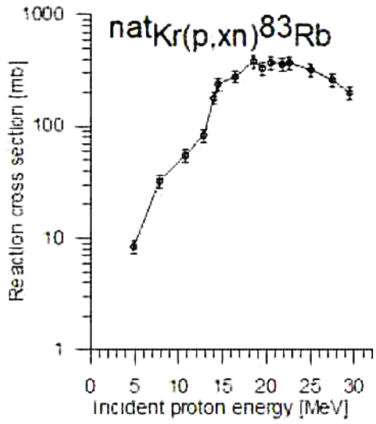

Figure 1: ^{83}Rb excitation function [3].

1. Motivation

The isomeric state ^{83m}Kr ($T_{1/2}$ = 1.8 h) produced in the decay of the isotope ^{83}Rb ($T_{1/2}$ = 86.2 d) decays to the stable ground state of ^{83}Kr through a cascade of the 32.5 and 9.4 keV electromagnetic transitions.

The well known low energy monoenergetic electrons of internal conversion of these transitions are suitable for the test, calibration and systematic measurements of the detector systems used in the dark matter [1] and neutrino mass [2] experiments.

2. ^{83}Rb production

The mother isotope ^{83}Rb is produced in the reaction of protons on the natural krypton gas. The abundances for A = 78, 80, 82, 83, 84, 86 amounts to 0.36, 2.3, 12, 12, 57, 17 %, respectively. The main contributing reaction is ^{84}Kr(p,2n)^{83}Rb. The excitation function for the formation of the ^{83}Rb on the natural krypton is presented in Fig. 1.

Smaller amounts of the accompanying radioactive isotopes ^{84}Rb ($T_{1/2}$ = 33 d) and ^{86}Rb ($T_{1/2}$ = 19 d) do not disturb in the ^{83m}Kr application because the intensity of their low energy electrons is weak.

For the irradiation of natural krypton with protons at the NPI cyclotrons a pressurised gas target is used.

3. Production method development

For the cyclotron U-120M (E_p = 26.5 MeV, I_p = 15 μA) and the new cyclotron TR-24 (E_p = 24 MeV, I_p = 45 μA), gradually four types of the targets from the aluminium alloy were developed and used within the period 2006-2020 (shown in Fig. 2):

- T1 (water cooling, krypton pressure 7.5 bar, proton current 6 μA, rate 14 MBq/hour of ^{83}Rb, 8 irradiations accomplished),

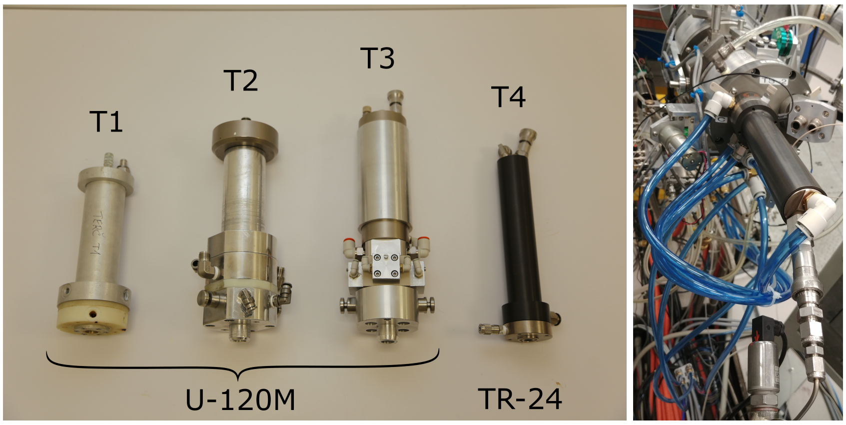

Figure 2: Left: The four developed targets. Targets T1, T2 and T3 were used with the cyclotron U-120M. Target T4 is used with the cyclotron TR-24. Right: Target T4 attached to TR-24 cyclotron. Blue tubes - water (target body) and helium (input windows) cooling, black cable - proton current measurement, cylindrical gauge – krypton pressure measurement.

- T2 (water + helium cooling of the proton input window, 13 bar, 15 μA, rate 52 MBq/hour, 21 irradiations),
- T3 (water + helium cooling, centering electrodes, 13 bar, 15 μA, rate 50 MBq/hour, 4 irradiations).
- T4 (water + helium cooling, 10 bar, 45 μA, rate 150 MBq/hour, 3 irradiations).

Up to now the most efficient target T4 was successfully used for the 12, 13 and 2 hour irradiations in which 1.7, 1.9 and 0.3 GBq of ^{83}Rb were produced. The share of ^{84}Rb and ^{86}Rb activities was 54‰ and 16‰, respectively.

There are further steps that are investigated for production optimization. Optimization of target length and irradiating at 25 MeV at TR-24 (needs a special cyclotron regime) reduces ^{84}Rb and ^{86}Rb production. Using an alloy with less Fe and Ni decreases the contamination with radioactive Co isotopes. Increasing defocusing of the proton beam at the target input windows reduces their local thermal load.

References

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