Measurements of the Fast Neutron Fluence and of the Neutron Spectrum of the Atomic Bomb of Hiroshima

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Comparisons between measured thermal neutron fluences derived from neutron activations to ^{36}Cl, ^{41}Ca, ^{60}Co, ^{152}Eu and ^{154}Eu, and fluences calculated in the actual dosimetry system DS86 show pronounced discrepancies. For distances r of about 1500 m from the epicenter of the bomb, the measured fluences are by a factor of about 10 larger than the simulations (see e.g. ref. [1]). Thermal fluences F can approximately be described by $F(r) \propto r^{-2}$ $e^{-r/L}$ with the attenuation length L. In DS86, L is obtained to be 134 m whereas from the measurements L is obtained to be about 220 m. Fast neutron fluences were detected in 1945 by measuring ^{32}P produced via the reaction $^{32}S(n_f,p)^{32}P$. Describing these data [2] by $F(r) \propto r^{-2}$ $e^{-r/L}$, L = 455 m is tentatively deduced (see fig. 1) in contrast to L = 212 m given in DS86.

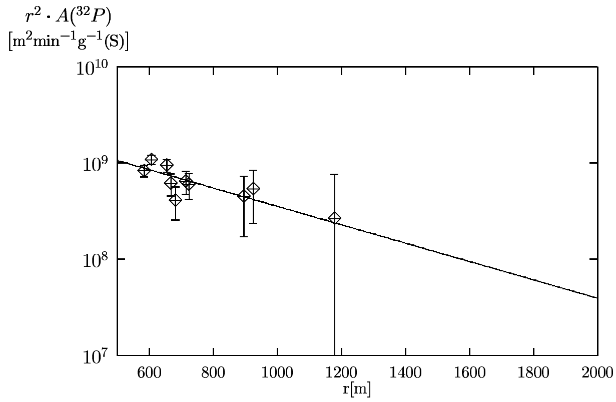

Fig. 1: Measured ^{32}P activities multiplied with r^2 as function of the distance r from the epicenter [2]. The data are fitted with the function $A(^{32}P) \propto r^{-2}$ $e^{-r/L}$ with L = 455 m

In addition, own measurements of the isotopes ^{36}Cl, ^{41}Ca, ^{60}Co, ^{152}Eu and ^{154}Eu in a granite gravestone 107 m from the hypocenter cannot be explained by DS86 [3]. On the other hand, the values of the neutron fluences show directly consequences for epidemiological studies. The deduced relative biological effectiveness for neutrons is larger for uncorrected neutron fluences in Hiroshima than for corrected ones. And the γ doses where the quadratic risk effect equals the linear risk effect also depend on neutron fluence corrections. Because of these very important implications, a new series of experiments was started to measure the fast neutron fluence and the neutron spectrum in Hiroshima. One attempt is the investigation of the fast neutron induced reaction $^{63}Cu(n_f,p)^{63}Ni$ (see the present annual report). In the present contribution, we describe new experiments to measure the fast neutron fluence as function of the distance from the hypocenter using the reaction $^{39}K(n_f,p)^{39}Ar$, and to determine the neutron spectrum by measuring the radionuclides ^{10}Be, ^{14}C, ^{39}Ar, ^{59}Ni and ^{131}Xe in the same granite gravestone in which the radionuclides ^{36}Cl, ^{41}Ca, ^{60}Co, ^{152}Eu and ^{154}Eu were already measured [3].

In granite, ^{39}Ar ($T_{1/2}$ = 269 y) is produced by the fast neutron induced reaction $^{39}K(n_f,p)$. In order to extract Argon, the granite has to be melted. After cleaning from other gases and noble gases, the ^{39}Ar activity will be measured in a low-background proportional counter.

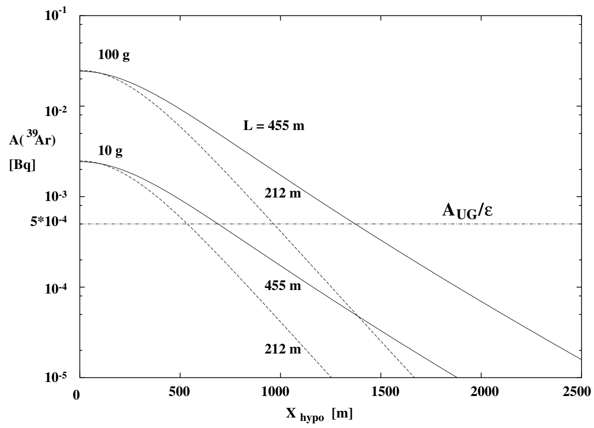

Fig. 2: Expected ^{39}Ar activities for 10 and 100 g granite samples as function of the distance from the hypocenter, for attenuation lengths of 212 m and 455 m, respectively. A_{UG} and ε are background counting rate and efficiency of the detector, respectively

Fig. 2 shows the expected ^{39}Ar activity as function of the distance x from the hypocenter for 10 and 100 g samples and attenuation lengths of 212 m (DS86) and of 455 m (^{32}P), respectively, in comparison to the ratio A_{UG}/ε of background counting rate A_{UG} to counter efficiency ε. It is seen that for the location of the gravestone a sample of a few grams is sufficient whereas for a distance of 1400 m a sample of about 100 g has to be analysed. For the measurement of the cross section $^{39}K(n,p)^{39}Ar$, potassium molybdate samples were irradiated with subthermal neutrons and neutrons in the energy range from 1.5 to 4 MeV.

For the determination of the neutron spectrum, different energy dependences of (n,γ), (n,p) and (n,α) cross sections can be used. The investigated reactions are $^{9}Be(n,\gamma)^{10}Be$, $^{10}B(n,p)^{10}Be$, $^{14}N(n,p)^{14}C$, $^{17}O(n,\alpha)^{14}C$, $^{35}Cl(n,\gamma)^{36}Cl$, $^{39}K(n,p)^{39}Ar$, $^{40}Ca(n,\gamma)^{41}Ca$, $^{58}Ni(n,\gamma)^{59}Ni$, and $^{130}Ba(n,\gamma)^{131}Ba$.

References

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