Detection of ^{63}Ni to Measure the Fast Neutron Fluence in Hiroshima

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In the presently used Dosimetry System DS86, neutron and γ-ray doses are calculated for the survivors of the Hiroshima and Nagasaki A-bomb explosions. Recent measurements show a large discrepancy between measured and calculated fluences for thermal neutrons [1,2]. For example, at distances of about 1 500 m from the explosion in Hiroshima the measured fluence of thermal neutrons is at least 10 times higher than calculated.

Therefore, a large uncertainty exists about the neutron dose the survivors in Hiroshima were exposed to. It is very important to solve this problem, because DS86 is an important component for the radiation risk assessment of the A-bomb survivors, which is in turn basis of radiation safety standards.

A measurement of fast neutrons should help to clarify this uncertainty. Fast neutrons were measured few days after the bombing using the reaction ^{32}S(n,p)^{32}P ($T_{1/2}$ =14.3 d). The results of these measurements represent the only direct detection of fast neutrons. Unfortunately, the errorbars of these measurements are too large for distances larger than 600 m from the hypocenter. Recently, it was suggested [3] to measure ^{63}Ni ($T_{1/2}$ =100 y) which was produced in Cu samples by fast neutrons via the reaction ^{63}Cu(n,p)^{63}Ni. Cu is commonly used and therefore appropriate samples like electrical wires and gutters are available. About $2 \cdot 10^4$ ^{63}Ni atoms/g Cu were produced at a distance of 1 500 m. With a Ni impurity in the sample of 19 ppm (measured in copper from Hiroshima) a ^{63}Ni/^{58}Ni ratio of about 10^{-13} is estimated. Therefore Cu is 18 oders of magnitude more abundant in the original samples. At Lawrence Livermore National Laboratory a method of chemical preparation was established to extract the ^{63}Ni from the copper and to prepare a sample holder for the ion source [4]. The gas-filled magnetic analyzing system (GAMS) [5] has an extremely good isobaric suppression in the mass range around 60. Therefore it seemed feasible to measure ^{63}Ni in copper samples from Hiroshima.

During the course of our studies it has turned out that most of the copper background originated from the ion source and not from the sample. Therefore we changed to a new ion source constructed with a very open structure, which allows excellent pumping near the sputter area [6]. Typical copper parts, like gaskets and electrical conductors, have been replaced by silver, nickel or aluminum. By use of this source and a nitrogen filled glove box for changing samples, it was possible to reduce the ^{63}Cu background by one to two orders of magnitude below the previous value of about ^{63}Cu/Ni $\approx$ 100 ppm. The improvements allow measurements down to a ^{63}Ni/Ni ratio of about 10^{-13}.

In order to test our sensitivity and accuracy, measurements were performed on copper wires irradiated by fast neutrons from a ^{252}Cf source. Fig. 1 shows a spectrum taken with an ionization chamber using a sample with a ratio of ^{63}Ni/^{58}Ni $= 2 \cdot 10^{-10}$. The fourth energy loss signal is plotted versus the position in the detector. Conditions have been set on the other parameters. The results for the wire samples are plotted in Fig. 2 versus their expected concentration. Since we reached even lower background levels in later runs, measurements in the range ^{63}Ni/Ni $\approx 10^{-13}$ which corresponds to a distance of about 1 500 m from the hypocenter seem to be feasible.

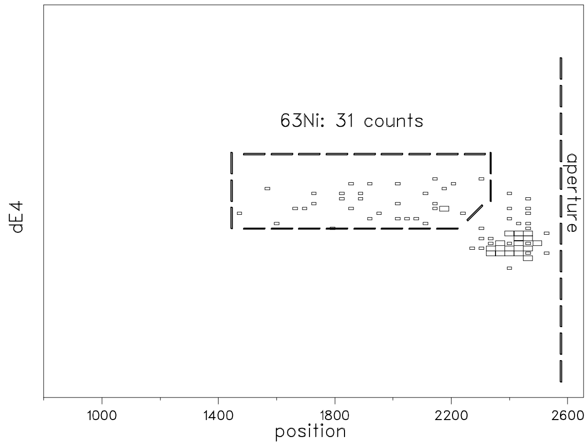

Fig. 1: Spectrum of energy loss versus position from a sample with ^{63}Ni/^{58}Ni $= 2 \cdot 10^{-10}$. The dashed rectangle contains ^{63}Ni events. To the lower right side the tail of the ^{63}Cu distribution is visible.

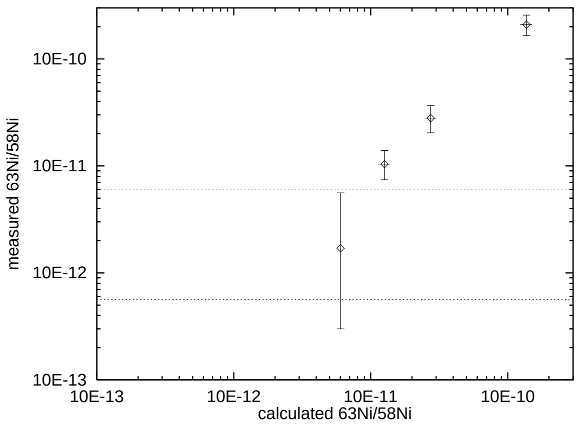

Fig. 2: Measured ^{63}Ni concentrations of samples produced by irradiation of Cu with fast neutrons versus their calculated concentration. The horizontal lines indicate the amount of background measured in blank samples.

References

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