^{63}Ni Produced by Fast Neutrons of the Hiroshima Bomb Status of Measurements

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In the past there were major concerns regarding the DS86 [1] radiation dose estimates for the survivors of the atomic bombing of Hiroshima and Nagasaki, see e.g. [2]. Particularly, calculated neutron doses for the survivors were in dispute, due to the lack of reliable experimental data on fast neutron fluences. Few weeks after the bombing of Hiroshima, measurements of ^{32}P ($T_{1/2}$=14.3 d) produced by fast neutrons via the reaction ^{32}S(n,p)^{32}P had been performed. However, these measurements did not allow the reconstruction of fast neutron fluences at distances from the hypocenter[1] where many people could survive. The majority of people, who are subsumed under the follow up of the Japan Life Span Study (LSS) [3] survived at distances beyond 1000 m from the hypocenter. In the present work we report on the very first measurement of fast neutron fluences in Hiroshima at these distances.

As proposed by Shibata and coworkers [4], and Marchetti and coworkers [5], fast neutron fluences could be determined in Hirohsima by measurement of ^{63}Ni ($T_{1/2}$=101.4 a) in copper samples where it was produced via the reaction ^{63}Cu(n_{fast},p)^{63}Ni. The feasibility to use AMS was shown in previous reports [6,7,8,9,10]. The detection limit achieved with GAMS setup in Munich is, in terms of the ^{63}Ni/Ni ratio, as low as $2 \cdot 10^{-14}$ [8,11]. This allows the detection of ^{63}Ni in copper samples from Hiroshima at ground ranges beyond 1000 m [8].

Our results in terms of ^{63}Ni per g Cu for samples from Hiroshima (table 1) shows fig. 1. Data are given for the date of measurement, and were corrected for ^{63}Ni concentrations measured in samples from large distances (SuB and KHS, weighted mean: $(7.1\pm2.4)\cdot10^4$ ^{63}Ni/g Cu) which serve as a reference. For comparison, the corresponding calculated DS86 free in air (FIA) ^{63}Ni/g Cu-ratios are also shown (based on DS86 FIA neutron fluences 1 m above ground, and on the ENDF/B-VI production cross section). Corrections for individual sample location and self-shielding were not yet applied, but are expected to be smaller than 20%.

All results are in reasonable agreement with DS86 predictions, with the exception of the BoJ sample. This has recently also been observed for other radionuclides produced by thermal neutrons in Hiroshima such as ^{36}Cl [12]. Together with results for the reconstruction of γ-ray doses, these observations suggest that the height of burst for Hiroshima has been underestimated.

For the interpretation of results obtained for samples from large ground ranges, a thorough investigation of the natural ^{63}Ni level in samples which were not exposed to A-bomb neutrons is important [13]. Therefore, our future research will also investigate the production of ^{63}Ni in copper samples due to neutrons, protons, photons and muons from cosmic radiation.

code	sample from building	r_{sl} [m]	type
BoJ	Bank of Japan	685	lightning rod
SSB	Soy Sauce Brewery	1 104	lightning rod
CH	City Hall	1 159	lightning rod
ES	Elementary School	1 442	rain gutter
RI	Radioisotope Building	1 570	rain gutter
SuB	Sumitomo Bank	1 967	rain gutter
KHS	Kusatsu-Hachiman Shrine	5 095	roof

Table 1: Locations of the copper sample in Hiroshima (with codes). r_{sl} denotes the distance to the epicenter. Preliminary results of measurements are shown in fig. 1.

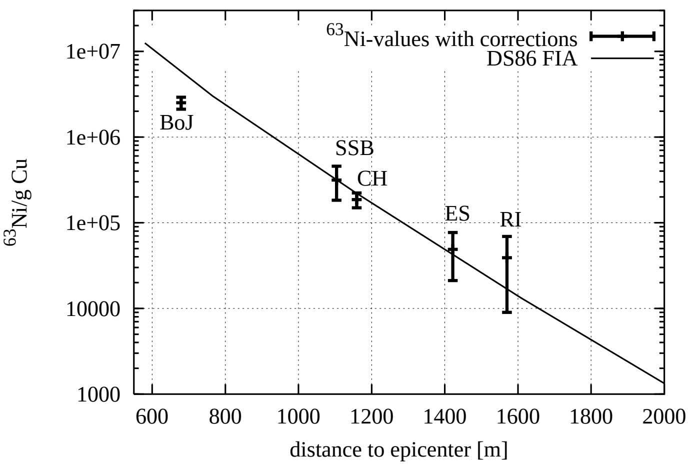

Fig. 1: Results of measurements of the ^{63}Ni-content in copper samples. Activation due to stable nickel and shielding corrections are not taken into account; abbreviations see table 1.

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[1] Hypocenter is defined as the vertical projection of the point of explosion (epicenter) to the ground. The distance from a point to the hypocenter is the ground range.