Study of Triggered Gamma Emission from ^{178}Hf using the YSU Miniball Array

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Nuclear metastable excited states, isomers, may be found in many isotopes and can store up to MeV per nucleus for decades [1]. It has been suggested that such states might serve as nuclear batteries without the production of radioactive by-products. Of more direct importance, isomers exist due to peculiarities of their coupling with electromagnetic radiation – therefore, studies of the interaction between isomeric nuclei and externally-produced photons can provide considerable insight into nuclear structure. Among the many isomers, ^{178m2}Hf, has attracted considerable attention. This isomer holds 2.445 MeV excitation energy with a half-life of 31 years, and it has been proposed that incident photons might trigger a release of this stored energy [2].

Several experiments have been performed to test this proposal, initially using bremsstrahlung and then moving to synchrotrons as studies concentrated on incident energies near 10 keV (see the review of Ref. [3]). While a number of experiments provided positive indications of triggering at modest statistical levels, other experiments gave null results. An initial test of low-energy triggering by this group at SPring-8 in 2003 found no evidence. In that effort, the principal technique involved acquisition of singles gamma spectra corresponding to irradiations over specific incident energy ranges, including near 10 keV. However, the latest positive reports emphasized that the promptness of the triggered gamma cascade was a major factor in null measurements [4]. The existence of such low-energy triggering, if proven, would challenge our understanding of the interactions between nuclei, atomic electrons and radiation. Thus, the issue remains open and worth additional study. The current experiment primarily concentrated on use of the YSU miniball array for sensitive detection of any prompt triggered events.

The YSU miniball is a compact multi-detector array which can serve as a rather efficient calorimeter for gamma-ray cascades. Its design and performance are described elsewhere [5], but the main point is that with a time resolution of about 35 ns it can measure the total energy emitted within a burst of gamma rays resulting from triggered or natural cascades within a sample.

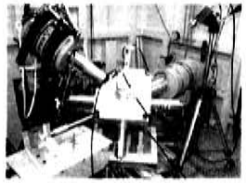

Figure 1: Experimental setup of the miniball array with supplemental independent detectors.

A bi-dimensional gamma-ray spectrum obtained by the miniball during irradiation of the sample with monochromatic photons at 9.567 keV is shown in Figure 2. The full γ-γ matrix of events has been sorted so that the figure displays events in which the master Ge detector (65% efficiency) plus any two of the array's BGO scintillators registered gamma photons within the system resolving time. At this point, there is no indication of prompt triggered decays although loci of natural decay events are clearly seen. A detailed analysis is continuing of the more than 80 GB of miniball data obtained during long runs at particular energies of the monochromatic SR and in scans over ranges of energies.

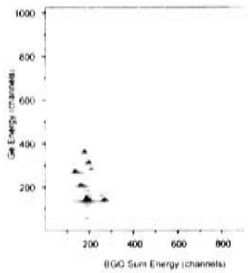

Figure 2: Bi-dimensional plot of γ-γ data obtained with the miniball during an irradiation at 9.567 keV.

References

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Anaerobic and Aerobic Structures of Ferredoxin II from *Desulfovibrio Gigas* Reveal Novel Electron Transfer Mechanism.

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Ferredoxin II (Fd II) is a small electron transfer protein, isolated from the strict anaerobic sulfate-reducing bacterium, *Desulfovibrio gigas*. The protein contains 58 amino acids and an iron-sulfur cluster. The cluster [3Fe-4S] spontaneously undergoes conversion to [4Fe-4S] when it is used as an electron mediator in the phosphoroclastic reaction. This two-form interconversion appears to have physiological significance. We have recently obtained both aerobic and anaerobic Fd II crystals of the high-resolution quality. Both structures are independently determined by the iron single-wavelength anomalous dispersion (Fe-SAD) method using synchrotron radiation X-ray.

Fig. 1. Structure of ferredoxin II.

The crystal structure of aerobic Fd II has been refined to 0.9 Å ultra-high resolution in the space group $P2_12_12$. Its [3Fe-4S] cluster is bound with Cys8, Cys14, and Cys50, whereas Cys11 extends away from cluster. Cys18 and Cys42 form a disulfide bridge to maintain the protein folding. Five isolated Zn^{2+} ions around the protein are located and bound with Glu, Asn and Asp, respectively, which indicates the transition metals, other than iron, could be incorporated into [3Fe-4S] center. On the other hand, the anaerobic Fd II structure from the crystals grown under anaerobic condition has also been determined and refined to 1.4 Å resolution. The anaerobic structure shows the different iron-sulfur cluster, disulfide bridge and cysteine residue conformations. Here we present the structure comparison between aerobic and anaerobic Fd II at ultra-high resolution for the first time which reveals the novel iron-storage function and electron transfer mechanism of ferredoxin II combining related proteins from *Desulfovibrio gigas*.

Fig. 2. The geometry of [3Fe-4S] cluster.