Observations on the long-lived Mossbauer effects of $^{93m}$Nb

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Several observations of the Nb long-lived Mossbauer phenomena are presented, in consequence of an irradiation increased by an order of magnitude compared with previous work. These are 1) two $β$ decays of $^{182}$Ta and $^{92m}$Nb are enhanced, i.e., $^{182}$Ta is now 200 times faster than in previous results while $^{92m}$Nb is twice as fast as normal; 2) $γ$-emitted from two $β$ decays compete to eject electrons in a winner-takes-all rule, rather than by superposition; 3) abrupt spectral changes reveal three decay phases of $^{182}$Ta; 4) the biphonon $γγ$ of $^{93m}$Nb is released from the sample for the first time; 5) the $γγ$ distribution is narrow, in contrast to the broad $γγ$ spectrum obtained from independent nuclei; 6) Nb $K$-lines super-radiate along the long sample axis; 7) collective scattering of multipolar MeV $γ$s. The manipulation of nuclear decay speeds demonstrated here highlights a potential application of this work in cleaning up the nuclear wastes.

To explain the resonant absorption of long-lived Mossbauer effects mediated by the biphonon $γγ$\$^−3$, a theory has been developed to interpret the variety of available experimental observations. A brief introduction to the physics of this theory and its extension to 4 entangled $γ$s is required. Results of $^{93m}$Nb experiments presented now reconfirm the large number of $^{103m}$Rh observations made before 2008\$^1,3$, which are briefly summarized in the Supplementary information.

In the multipolar nuclear transition of long-lived Mossbauer nuclides\$^4$, simultaneous $γγ$ occur in opposite directions to preserve the $γ$ energy by eliminating their recoil energy. Once resonant absorption occurs between two identical nuclei in the same neighbourhood, the probability of spontaneous $γ$ emission yields a superradiant factor of $\sqrt{N}$. The spontaneous $γγ$ emission thus becomes $\sqrt{N}$-fold effective in a crystal containing $N$ identical nuclei in resonance\$^5$.

Delocalised $γγ$ absorb $N$ phonons to acquire a mass, in the form of the so-called nuclear exciton\$^1$, having an emerging magnetic quantum number of $m = 0$. The exciton spreads in a region containing $N/M$ identical nuclei in a micron range with $M (\sim 10^{15})$ excitons and $N (\sim 10^{22})$ nuclei in a crystal.

The AC Stark effect produces Rabi sidebands around the characteristic $γ$s, regardless of atomic or nuclear transitions\$^\text{1,4}$. Mollow triplets\$^\text{2,3}$ were observed for Rh $K$-lines and $^{103m}$Rh $γ$ at 39.8 keV. The vacuum Rabi oscillation $Ω_R$ for $M/N < 1/2$ is so fast that the recoil phonon never leaves, leading to an entanglement between $γγ$ and the phonon.\$^5$ The superradiance has an Avogadro number of $N$ rather than $N^{1/2}$, resulting from the superposition of $N$ nuclei $×$ $N$ phonons in resonance\$^1$. A detailed evaluation provided in the Supplementary information reveals the $^{103m}$Rh superradiance $\sim 10^{28} \gg N$. The old model of $^{103m}$Rh given in the previous report\$^1$ is therefore incomplete.

Neither $^{93m}$Nb $γγγ$ nor its Rabi splitting has previously been observed\$^1\text{−}3$, and till now the exact value of $Ω_R$ has not been known. Nevertheless, $Ω_R$ must be greater than 30 meV in order to survive the thermal agitation at room temperature. Assuming that the M4 $Γ_{3}/Γ_{4}$, branching ratio is mainly attributed to the low-lying E2 Raman transition as well as the nuclear size\$^6$, we fine-tuned the value of the $^{103}$Ba $11/2^−$ excited state for $^{93m}$Nb to $10^{-6}$.

Four factors, i.e., the 30-meV $Ω_R$, the 16-year half-life, the internal conversion, and the $Γ_{3}/Γ_{4}$, branching ratio, give a $γγ$ superradiance $\sim 10^{31}$. The rotational symmetry of $^{93m}$Nb is spontaneously broken by the absorption of N nuclear magnons\$^{10}$.

Applying the new observation of $Ω_R\sim 100$ eV, the superradiance becomes $\gg N^{3/2}$ and the above-mentioned $^{93m}$Nb model is again incomplete. Bosonic excitons prefer antiferromagnetic ordering to lower the energy. There are two magnon polarizations in the antiferromagnetic ordering. The M4 excitation of $^{93m}$Nb may consist of a pair

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Results
Figure 1 shows the decays of four x-rays, where Ta $\gamma = 67.8$ keV represents the $\beta$ decay of $^{182}$Ta and Zr K\(\alpha\) represents the electron capture + $\beta^-$ decay of $^{92m}$Nb. X-rays have two characteristic time constants corresponding to $^{92m}$Nb and $^{182}$Ta. The contributions of the slow $^{93m}$Nb (half-life of 16 years) and $^{94}$Nb (half-life of $2 \times 10^4$ years) are negligible. The varying time constants are demonstrated by the initial 9 data points of the four decays shown in Fig. 1, which were taken in the same position during the period of hazardous radioactivity.

The initial sample position with inclination was replaced by a contact position at day 12. The calibration between the two positions using the same activated sample (Fig. 1) demonstrates an interesting anisotropy at about 20%. More anisotropic x-rays are shown in the Supplementary information. We conclude that the main phenomenon discussed here.

The first 7 data points of Ta $\gamma$ shown in Fig. 1 depict a chaotic decay of $^{182}$Ta, which is, however, at least three times faster than the normal half-life of 114.43 days. This enhanced decay then relaxes within 10 days. Taken together, the 160 data points give a 3% enhanced half-life of 111.4 ± 0.3 d. The Hf K-lines (see Fig. 3 and Fig. S2 in the Supplementary information) appear to follow the $^{182}$Ta decay. An $\alpha$ branching channel to reach a stable $^{178}$Hf from $^{182}$Ta is considered.

With some care we inspected the high-energy $\gamma$s using an HPGe detector. Only the characteristic $\gamma$s emitted from the $^{182}$Ta and the $^{94}$Nb decays were found (see Figures S6 and S7 in the Supplementary information). The readings of two $\gamma$s @ 706.2 keV and @ 871.1 keV reveal the major excitation of $^{94}$Nb in the sample, the density of which was ~1000 times higher than the $^{182}$Ta density at day one. Neither the MeV $\alpha$ particle nor the characteristic $\gamma$s of $^{178}$Hf or $^{178}$Lu were found. The MeV $\alpha$ particles escaping from the sample were probably too rare to be caught by the $\alpha$-particle detector used. Figure 2 shows that the Hf K-lines disappeared after day 116, when the Zr K\(\alpha\) from $^{92m}$Nb decayed to 0.03 counts per second (cps). We observed the same transition at 0.02-cps Zr K\(\alpha\) using the same detector from the sample of a similar size in 2012. At around the same time, the ratio of W K\(\alpha\)/Ta $\gamma$ increased from 0.70 to 3.9 after day 116.

The $^{92m}$Nb decay is characterized by the Zr K\(\alpha\) in Fig. 1. Again, the first 7 data points reveal a doubled decay speed, which recovered to the normal half-life of 10.15 d within 10 days. $^{92m}$Nb is an isomeric $\gamma$ excitation of $J^\pi = 2^+$. The 135-keV M5 transition to the $^{94}$Nb ground state of $J^\pi = 7^+$ is negligible with respect to the major $\beta$ decay channel$^3$. The Nb K-lines with a half-life of 4.2 days strictly follow the $^{92m}$Nb decay.

Figure 1. Decays of four x-rays in counts per second (cps) against their reference lines of half-lives listed below. The left-hand axis shows the rates of Nb K\(\alpha\) (black dot, 111.4 d), Nb K\(\beta\) (orange square, 111.4 d), Ta $\gamma$ (blue diamond, 111.4 d), and the right-hand axis shows the rates of Zr K\(\alpha\) (green star, 10.15 d). Removing its contamination makes Zr K\(\alpha\) very sensitive to the temperature shift of the spectra. Data points of Zr K\(\alpha\) after day 51 are deleted because of their overly large fluctuation. The hollow symbols show data points measured at the contact position. The data points taken at the incline position are multiplied by a factor of calibration using the detected total counts (see Fig. S1 in the Supplementary information). The inset shows the calibration between two measuring positions, where the K x-rays of Nb and Zr are anisotropic. The details of the first 7 data points and their reference lines are shown in the insets blow.
The FWHM of $\gamma$ was just disappearing at the moment, at which the spectral change took place. The vertical black line highlights the $\gamma\gamma$ energy of 15.4 keV. Another peak is probably located at 15.9 keV (see Fig. 3 and S4 in the Supplementary information). Therefore, a conservative estimate gives the $\gamma\gamma$ FWHM of $\sim$600 eV, which then gives a true $\gamma\gamma$ FWHM of $\sim$400 eV.

Figure 3 shows the spectral evolution in two periods. We decomposed the 160 spectra in the contact position using two characteristic half-lives (111.4 and 10.15 d), as shown in Fig. 4 using the equation

$$\text{Spectra}(i) = \exp[-t(i)/111.4d] \text{Ta}(i) + \exp[-t(i)/10.15d] \text{Zr}(i),$$

where Spectra$(i)$ are the count rates in the 8192 channels, Ta$(i)$ are x-rays contributed by the $^{182}$Ta decay, Zr$(i)$ are x-rays contributed by the $^{92}$mNb decay of, $i$ is the index of 160 data points, and $t(i)$ is the time of measurement. No x-rays strictly depend on $^{92}$mNb, except for the Zr K-lines and a peak @ 14.7 keV (see Fig. 4). We failed to identify this $\gamma$ @ 14.7 keV to be the left Rabi sideband of Zr K$_\alpha$, because its right Rabi sideband is invisible beneath the Nb K$_\alpha$ peak. Another small peak @ 17.5 keV follows the $^{182}$Ta decay, which may be the right Rabi sideband of Nb K$_\alpha$. Its left counterpart @ 15.9 keV is difficult to identify in Fig. S3 and S4 of the Supplementary information. The two sidebands disappeared together after day 116 (see Fig. 2). No pronounced spectral migration of Nb K-lines given in previous work$^2$ was found in these 160 data points.

V K$_\alpha$ (4.95 keV) and V K$_\beta$ (5.43 keV) with a branching ratio of 10:1 are identified to be the impurity channel of V, which has a similar time-varying time constant to that observed for the Ni impurity channel in previous work$^2$ (see Fig. S2 in the Supplementary information).

Two pronounced peaks, i.e., $\gamma\gamma$ @ 15.4 keV (E$_2$/2) and Quad @ 7.5 keV, emerge in Fig. 4, the time constant of which strictly matches the $^{182}$Ta decay, except for the first 7 data points. The Quad peak is apparently not the Ni K$_\alpha$ in previous work$^2$, because the corresponding Ni K$_\beta$ is entirely absent. Furthermore, the broadband x-rays spread over the entire spectrum also follow the $^{182}$Ta decay. Two peaks of $\gamma\gamma$ and Quad disappeared with the Hf K-lines together after day 116 (see Fig. 2), when the low-energy broad-band x-rays between 2 and 5 keV abruptly increased by a factor of more than three, from 9 cps to 30 cps.

The low-energy broadband x-rays remained unchanged on insertion of a 0.1-mm Pb foil after day 116 (see Fig. S5 in the Supplementary information), while they are reduced overall following insertion of a thin Al foil before day 116 (see Fig. 5). The exponential shape seen in Fig. S5 (not a Compton plateau) reveals the random arrivals of a short-burst $\gamma$ is isotropically emitted into the 4$\pi$ solid angle, which are probably generated by multipolar $\gamma$ after day 116. The short burst lasted less than 120 ns. Multiple $\gamma$s arriving at the detector are thus treated as a single count by the multi-channel analyzer, which reports a 100% live-time. The 70% live-time before day 116 reveals a long burst of a $\gamma$ train, which is probably generated by the speculated $\alpha$ particle.

We inserted the Al filter layer by layer just one week before the spontaneous spectral change at day 116. The photo-electric attenuations of one 25-μm Al foil are roughly 30% @ 7.5 keV and 6% @ 15 keV, respectively. Figure 5 and Table 1 show the results obtained using increasing numbers of Al layers. The photo-electric attenuations of $\gamma\gamma$ and Quad are obviously abnormal. We conclude that these represent entangled $\gamma$s emitted from $^{93}$mNb.

The ratio of Nb K$_\alpha$/Ta $\gamma$ in Fig. 2 increased from 6 to 8 by rotating the sample to the longitudinal position, while the broadband x-rays between 2 and 5 keV increased by 50%. The 15.4-keV $\gamma\gamma$ was just disappearing at the moment of rotation of the sample, and it disappeared altogether on rotation back to the contact position half an hour later. The FWHM of $\gamma\gamma$ was $\sim$600 eV (see Fig. 2).

We applied three multipolar MeV $\gamma$s from $^{137}$Cs and $^{60}$Co, i.e., 662 keV (M4), 1173 keV (E2), and 1333 keV (E2), to demonstrate the collective scattering of nuclear exciton in Table 2. The collective scattering strongly
depended on the multipolarities of impinging $\gamma$ s. The dead time of detector in Table 2 reelected the total incoming counts. The impinging E2 $\gamma$s increased 10% of the internal $\gamma$s from the $^{182}$Ta decay, while only increased 1% of the total counts. The M4 $\gamma$s did not change the total counts and the internal $\gamma$s too much.

Instead, more M4 $\gamma$s was scattered away by the nuclear exciton. The M4 $\gamma$s @ 662 keV from $^{137}$Cs is also a long-lived Mossbauer $\gamma$ with a half-life of 2.55 minutes, the first-order thermal Doppler shift of which vanishes$^{11}$. We estimate its coherent length $\sim 100$ m using the second-order Doppler shift. In contrast, the coherent lengths of E2 $\gamma$s from $^{60}$Co are on the $\mu$m order, as restricted by the first-order Doppler shift.

Discussion

Although no atomic transition emits x-rays $>$ 120 keV, we observe broadband x-rays over a wide range of energies beyond 200 keV, the distribution of which contains no Compton plateau (see Fig. 2). These broadband x-rays followed the slow $^{94m}$Nb decay in the old single-crystal sample$^4$, when $^{182}$Ta vanished in 2015. $^{93m}$Nb cannot provide x-rays $>$ 30 keV, so we must have a coincident arrival of multiple $\gamma$s, as revealed by inserting a filter (see Fig. 5 and Fig. S5 in the Supplementary information). These facts reveal the presence of a high-energy source in the sample, which we then identify as $^{94}$Nb.

One $^{94}$Nb decay gave roughly one $^{92m}$Nb decay probably via a Raman branching at day one. Two E2 $\gamma$s from $^{94}$Nb scatter the $^{92m}$Nb to the virtual 4$^+$ or 6$^+$ states, which return to the $^{92}$Nb ground state shortly. A similar Raman scheme doesn't apply for $^{93m}$Nb, because there is no available 6$^-$ state of $^{92}$Nb$^4$. It requires an extreme Raman cross-section to double the $^{92m}$Nb decay speed. The following discussions are an attempt to shed some light on these matters.

This enhanced Raman scattering should not spontaneously stop within 10 days, unless the multipolar $\gamma$s emitted from the $^{92m}$Nb decay or the $^{92m}$Nb excitations themselves cooperated with each other. The E2 $\gamma$s @ 0.93 MeV emitted from the $^{92m}$Nb decay has a near-resonant coupling with the E2 transition @ 0.95 MeV of $^{93}$Nb. Coherent $^{97}$Nb nuclei in an exciton provide a collective scattering, which is amplified by a factor of $\sim 10^{10}$ giving rise to a strong exciton-field coupling with a $\Omega_\nu > 1$ MeV$^{7,8}$. MeV E2 $\gamma$s are therefore stored in a small “cavity” of the $\mu$m-size exciton. Note that E2 $\gamma$s in Table 2 are from an external source. The internal E2 $\gamma$ sources shall coherently...
move with the surrounding nuclei, that tremendously enhance the coupling strength. The photonic reservoir may thus provide a spontaneous cooperation to terminate the accelerated $^{92}\text{m} \text{Nb}$ decay. This strong coupling also

Figure 4. Accumulation of the decomposed spectra. Line C1 obtained using differential mapping between lines B1 and B2 + B3 under the condition of cancelling Ta $\gamma$ @ 67.8 keV; line C2 is the spectrum Ta(i) decomposed using eq. 1 with a half-life of 111.4 d; line C3 is the spectrum Zr(i) decomposed using eq. 1 with a half-life of 10.15 d. C2 contains x-rays following the $^{182}\text{Ta}$ decay. C3 contains x-rays following the $^{92}\text{m} \text{Nb}$ decay. Note that the left Rabi sideband of Nb K$\alpha$ shows up at right hand side of the non-Gaussian $\gamma \gamma$ peak @ 15.4 keV of C2 line. Two figures C1 and C3 are very different, i.e., C1 contains Nb x-rays and the biphoton $\gamma \gamma$, while C3 does not.

Figure 5. Coincident arrival of multiple $\gamma$s at the detector. The spectral ratio between no-layer and 3-layer Al foils is obtained by normalizing the Ta $\gamma$ @ 67.8 keV and an average of Gaussian with a sigma of 10 channels. The energy positions of the Quad, the W L$\alpha$, the $\gamma \gamma$, and the Ta $\gamma$ are highlighted by the vertical lines. The inset shows the development of the highlighted peaks by inserting Al foil layer by layer, the numbers of which are given in Table 1. Note the Quad count @ 7.5 keV deceased much less than the W L$\alpha$ count, while the $\gamma \gamma$ increased on insertion of Al foils. Decreasing broadband x-rays all over the spectral range reveals they are coincident arrivals of multiple $\gamma$s. We failed to identify a peak located @ 6.39 keV.
the photo-electric attenuations of six x-rays, i.e., Nb Kα, Nb Kβ, γγ, W Lα, W Lβ, and Quad, by comparing their ratios between inserting 1, 2, 3 layers of Al foil and no Al foil. The ratios of the Ta γ counts at 67.8 keV are normalized to be unity. Note that the γγ ratios are greater than the Nb Kα ratios by 3 sigma, while the Quad ratios are greater than the W Lα ratios by 70 sigma.

| Layer/X ray | Nb Kα | Nb Kβ | γγ | W Lα | W Lβ | Quad |
|-------------|-------|-------|----|------|------|------|
| 1           | 0.958 ± 0.004 | 0.974 ± 0.006 | 0.970 ± 0.006 | 0.774 ± 0.010 | 0.876 ± 0.007 | 0.97 ± 0.02 |
| 2           | 0.985 ± 0.004 | 1.014 ± 0.005 | 0.996 ± 0.006 | 0.589 ± 0.009 | 0.727 ± 0.007 | 0.90 ± 0.01 |
| 3           | 0.946 ± 0.002 | 0.990 ± 0.003 | 0.955 ± 0.003 | 0.421 ± 0.005 | 0.579 ± 0.004 | 0.900 ± 0.005 |

Table 2. Collective scattering of multipolar MeV γs. Two sources of 137Cs and 60Co provided three major γs, i.e., 662 keV (M4), 1173 keV (E2), and 1333 keV (E2). No significant scattering (<3%) was found by inserting a pristine sample beneath two sources. In contrast, only 90% of the MeV γs penetrated the active sample. Data in cps were taken with a live time of 1000 s in two sample locations, either beneath the source (0 cm) or near the source (1 cm). Note that 10% of the E2 γ @ 1121 keV from the 182Ta decay in sample was released by the 60Co source, while the total counts increased only 1%.

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| Source | Sample location | Real time | 1121 keV | 662 keV | 1173 keV | 1333 keV |
|--------|-----------------|-----------|---------|--------|---------|---------|
| No     | 0 cm            | 1262 s    | 336.7 ± 0.7 | —      | —       | —       |
| No     | 1 cm            | 1221 s    | 300.3 ± 0.6 | —      | —       | —       |
| 137Cs  | 0 cm            | 1282 s    | 337.0 ± 0.7 | 101.5 ± 0.5 | —       | —       |
| 137Cs  | 1 cm            | 1243 s    | 301.0 ± 0.6 | 108.6 ± 0.5 | —       | —       |
| 60Co   | 0 cm            | 1274 s    | 369.3 ± 0.7 | 10.7 ± 0.2 | 15.3 ± 0.2 | —       |
| 60Co   | 1 cm            | 1233 s    | 301.3 ± 0.5 | 11.8 ± 0.2 | 16.4 ± 0.2 | —       |

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The energy distribution of an individual $\gamma\gamma$ is usually very broad, while a narrow width shows up the non-Gaussian FWHM of 130 eV and 170 eV at the contact and incline positions, respectively (see Fig. S3 in the Supplementary information). The $\gamma\gamma$ width further increased to 400 eV at the longitudinal position (Fig. 2). According to our theory, the $\gamma\gamma$ width will be the 0.03-eV $^{125}$I decay energy. The $\gamma\gamma$ peak is thus a quintuplet mainly contributed by a $\Omega_{+}$=100 eV of $m=\pm 1$ at the contact position. The pronounced broadening of the $\gamma\gamma$ FWHM in the longitudinal position reveals the anisotropic $\gamma\gamma$ of $m=\pm 2$ with a $\Omega_{0}$=200 eV. The speculated 800-eV Rabi sidebands around Nb K$_{0}$ in Fig. S3 is probably driven by $\Delta$ with a 200-eV $\Omega_{0}$, which disappear most likely due to the parity change after day 116.

**Conclusions**

The well-known photonic physics as promoted by the AMO society has been extended to the realm of nuclear physics in this report. We suggest that multipolar $\gamma$s from $^{94}$Nb stored in a photonic reservoir accelerate two different $\beta$ decays. $^{182}$Ta $\beta$ decay abruptly switches its branching channels, as dictated by the parity of diluted $^{92m}$Nb. Multipolar $\gamma$s emitted from two different $\beta$ decays compete with each other, rather than superposing together to eject the Nb K electron. Their Raman cross-sections are extremely large. The superradiance along the long sample axis reveals a coherent enhancement of Nb K-lines, which have no intrinsic coherence at all. The Nb K-lines cannot leave the coherent trace-records in the sample, unless a photonic reservoir exists. Taking these observations together leads us to a long-predicted coherence for all $^{92}$mNb excitation in the crystal. The superradiance of $^{10}$B $\rightarrow$ $^{10}$N gives rise to the reported $\gamma\gamma$ model.

**Methods**

In a set of experiments, we newly activated four niobium polycrystalline sheets of 99.99% purity (3 cm × 1.5 cm × 1 mm). We refer to sample No. 3 in this work. The method is as detailed in the reference 1, except that the irradiation time was two hours without the Cd shielding. The $^{92m}$Nb density was thus increased by a factor of 20 compared with the previous result. We used the same silicon detectors located at Hsinchu in the previous report, which are the Si-PIN type (XR-100CR) manufactured by AMPTEK in Bedford, MA 01730, USA. The window of the detector; and 3) a longitudinal position: the 3-cm long sample axis is parallel to the normal vector of the beryllium window in the longitudinal position. The sample area fully covers the 0.5-inch beryllium widow of detector at the contact position. Three samples (No. 1, No. 2, and No. 3) were wrapped by 5 layers of 0.1-mm Pb foil together, such that the Pb shielding opened an area of three surfaces (1 mm × 1.5 cm) in contact with the beryllium window in the longitudinal position.

Two kinds of filter were inserted between the sample and the beryllium window. One was a 25-μm Al foil, the other was a 0.1-mm Pb foil. Their photo-electric attenuations were verified by the calibration sources of $^{241}$AM and $^{55}$Fe.

The live-times of detector were insensitive to the incoming rate during the calibration between incline position and contact position, i.e. 70% for 120 cps and 230 cps, respectively. However, it changed to 100% after day 116.

We cooled the sample in liquid nitrogen between day 53 and day 81. Two detectors of the same type are applied, i.e., one for the measurements before day 116 and the other for the measurements after day 116. The first detector failed to work at day 116 and it was replaced by the second detector.

The high-energy x-rays were taken by a HPGe detector (CANBERRA GC0518, Coaxial-Ge type) with a 4.25 cm and a length of 4.1 cm, which was calibrated by $^{137}$Cs (10 μCi), $^{60}$Co (1 μCi) and $^{241}$AM (1 μCi) and located in a box of the 3 cm Pb shielding. The temperature of measuring environment was stable (27 ± 0.5°C). We manipulated the dead time of HPGe detector to avoid any possible pile-up errors induced by the $^{182}$Ta decay in the samples, when 20% dead time appeared in Table 2.

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**Acknowledgements**

We thank Dr. Tai-Ching Fan, the CEO of Ho Kang Technology Co. for his support for this project in purchasing and fabricating the pure Nb samples. We thank Prof. Yi-Gang Yang for the $\alpha$ detection, and Prof. Hong-Jian He for the discussion on the broken rotational symmetry.

**Author Contributions**

Y.C. undertook the data preparation, and the theoretical and the experimental works; S.-H.Y. undertook the data preparation; M.L. carried out the detector calibration, the sample activation and the measurements under hazardous radioactivity; C.-H.L. undertook the sample activation, and the measurements using an HPGe detector.
Additional Information

Supplementary information accompanies this paper at http://www.nature.com/srep

Competing financial interests: The authors declare no competing financial interests.

How to cite this article: Cheng, Y. et al. Observations on the long-lived Mössbauer effects of \(^{93m}\)Nb. Sci. Rep. 6, 36144; doi: 10.1038/srep36144 (2016).

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