Observation of the 2⁺ isomer in ⁵²Co

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We report the first observation of the 2^+ isomer in 52 Co, produced in the β decay of the 0^+ , 52 Ni ground state. We have observed three γ -rays at 849, 1910, and 5185 keV characterizing the β deexcitation of the isomer. We have measured a half-life of 102(6) ms for the isomeric state. The Fermi

and Gamow-Teller transition strengths for the β decay of 52m Co to 52 Fe have been determined. We also add new information on the β decay of the 6^+ , 52 Co ground state, for which we have measured a half-life of 112(3) ms.

a nan-me of 112(5) ms.

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I. INTRODUCTION

 β -decay spectroscopy is a fundamental tool for the investigation of the nuclear structure of unstable nuclei [1– 4]. Many neutron-deficient fp-shell nuclei lie on the astrophysical rp-process reaction pathway. Accordingly the study of the β decay of such nuclei is of importance because it provides input to calculations of the rp-process and models of X-ray bursters [5, 6]. The investigation of the decay of these nuclei is difficult because they lie far away from stability. The odd-odd nuclei are particularly difficult to study because there are often two long-lived states, one of which is the ground state, with similar halflives. This makes it hard to disentangle the two decays. This is because both states are in general members of the same two-particle multiplet and have therefore very similar structure. The only difference is how the spins of the valence nucleons couple to make the final spin. One strong contribution to the half-life is given by the Fermi transition, which is very fast and has identical strength in the two cases. How different the total half-life will be for the two states will thus depend on the details of the Gamow-Teller transitions. Here we present information on one such case. 52 Co is a $T_z = -1$ odd-odd isotope in the $f_{7/2}$ shell that was first observed in an experiment performed at GANIL [7]. There had been previous indications of the existence of a long-lived β -decaying excited

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state but it had not been isolated experimentally [8].

The 52 Mn nucleus, the mirror of 52 Co, has a 2^+ isomeric state at 378 keV above the 6⁺ ground state. This ⁵²Mn isomer, having a half-life of 21.1(2) min [9, 10], decays via two branches, 98.22(5)% by β^+ decay to 52 Cr and 1.78(5)% via an internal transition to the ground state [10, 11]. Assuming isospin symmetry, a 2⁺ isomeric state is also expected in ⁵²Co at a similar energy. This would mean that we have the case of two states with $J^{\pi} = 2^{+}$ and 6^{+} , corresponding to the 2^{+} and 6^{+} members of the $(\pi f_{7/2})^{-1}(\nu f_{7/2})^{-3}$ multiplet. The Fermi partial half-life will be of the order of 200 ms, and the total half-life will depend on the distribution and population of the low-lying 1⁺, 2⁺, 3⁺ states in the ⁵²Fe daughter for the decay of the 2⁺ isomer, and of the 5⁺, 6⁺, 7⁺ states in 52 Fe for the decay of the 6^+ ground state. For instance, in the very similar case of 44 V, with probable structure $(\pi f_{7/2})^3 (\nu f_{7/2})^1$, the two states with $J^{\pi} = 6^+$ and 2^+ have half-lives of 150(3) ms and 111(7) ms [8], respectively.

We have studied the β^+ decay of 52 Ni to 52 Co in Ref. [12]. A study of the high-spin states in 52 Co has been carried out recently [13]. The β^+ decay of 52 Co to 52 Fe was studied in Ref. [8]. The 52 Co ground state, having $J^{\pi}=6^+$ and T=1, undergoes β decay to its Isobaric Analogue State (IAS) in 52 Fe at 5655 keV [8]. Since the proton separation energy is 7378(7) keV [10] proton emission is not possible here. A cascade of four γ -rays (1329, 1942, 1535 and 849 keV) was reported in Ref. [8] corresponding to the de-excitation of the IAS in 52 Fe through the sequence

 $6^+(T=1) \rightarrow 6^+ \rightarrow 4^+ \rightarrow 2^+ \rightarrow 0^+$ [also shown in our decay scheme in Fig. 3(b)]. The measured γ -ray intensities in Ref. [8] implied the existence of a 31(14)% β feeding to the first excited state in 52 Fe at 849 keV $(J^\pi=2^+)$, which is quite unlikely to be due to direct feeding from the 6^+ state considering the $\Delta L=4$ difference between the parent and daughter states. It was therefore suggested in Ref. [8] that this anomaly could be explained by extra feeding associated with the decay of 52m Co, although no clear evidence could be found.

In the present paper we report the first observation of the 2^+ isomer in $^{\bar{5}2}$ Co, which was populated in the β decay of ⁵²Ni. The trick here was not to look at ⁵²Co as a direct product of the fragmentation reaction, but as a product of the decay of the 0⁺, ⁵²Ni ground state (see the partial decay scheme in Fig. 3(a)]. This decay process directly populates the $0^+(T=2)$ IAS in 52 Co, which then de-excites via the sequence $0^+ \to 1^+ \to 2^+$ [12]. This is a much cleaner way to populate the expected 2⁺ isomeric state. We have observed the γ -rays emitted following the β decay of the isomer and measured its half-life. The β -decay Fermi and Gamow-Teller transition strengths, B(F) and B(GT), have been determined [an upper limit] for B(F)]. Moreover, selecting the direct production of 52 Co we could obtain data on the β decay of the 52 Co, 6^+ ground state, which allowed us to add new information on this decay and measure the half-life with improved precision.

II. THE EXPERIMENT

We have studied the β^+ decay of 52 Ni to 52 Co in an experiment done at GANIL [12]. 52 Ni was produced by fragmenting a 58 Ni²⁶⁺ primary beam, accelerated to 74.5 MeV/nucleon, on a 200- μ m-thick natural Ni target. 52 Co was also produced directly in the same experiment. After selection of the fragments in the LISE3 separator [14], they were implanted into a 300- μ m-thick Double-

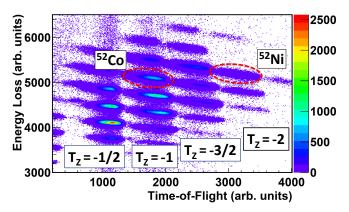


FIG. 1: ΔE versus ToF identification plot for the dataset optimized to implant $^{56}{\rm Zn}$ close to the middle of the DSSSD (see Ref. [12] for details). The positions of the $^{52}{\rm Co}$ and $^{52}{\rm Ni}$ implants are shown.

Sided Silicon Strip Detector (DSSSD). The DSSSD was used to detect both the implanted heavy ions and subsequent charged-particle (β particles and protons) decays. Four EXOGAM Germanium clovers [15] surrounding the DSSSD were used to detect the β -delayed γ -rays.

The ions were identified by combining the energy loss signal generated in a silicon ΔE detector located 28 cm upstream from the DSSSD and the Time-of-Flight (ToF), defined as the time difference between the cyclotron radio-frequency and the ΔE signal (see Figs. 1 and 2). An implantation event was defined by simultaneous signals from both the ΔE detector and the DSSSD. A decay event was defined by a signal above threshold in the DSSSD and no coincident ΔE signal.

The experimental setup is described in detail in Ref. [12], as well as the data analysis procedures employed.

III. THE ⁵²CO, 2⁺ ISOMER

In order to study the decay of the 2⁺ isomer in ⁵²Co, we have selected the events where ⁵²Ni was implanted (see Figs. 1 and 2). For the following discussion we refer to the partial decay scheme shown in Fig. 3(a), which starts from the β^+ decay of 52 Ni to 52 Co and then to 52 Fe. The β decay of ⁵²Ni [12] populates the 0⁺(T=2) IAS in ⁵²Co at 2926(50) keV with a β feeding of 56(10)%, consistent with the expected Fermi strength B(F) = |N - Z| = 4. Thereafter the decay of the IAS proceeds 25(5)% of the time by proton emission to ⁵¹Fe and 75(23)% of the time by a γ -ray cascade. The cascade consists of γ -rays of 2407 and 141 keV energy, with intensities I_{γ} of 42(10)% and 43(8)%, respectively, and populating in sequence the levels at 519(50) $(J^{\pi} = 1^{+})$ and 378(50) $(J^{\pi} = 2^{+})$ keV in ⁵²Co. As explained in detail in Ref. [12], we have assumed for the last level an energy of 378(50) keV from the value in the mirror nucleus ⁵²Mn, 377.749(5) keV [10, 16], fixing in this way the excitation energies for the ⁵²Co levels. The error of 50 keV on the 378 keV level energy, which accounts for possible mirror energy differences (MED), was estimated in Ref. [12] by looking at the energies of the levels up to 400 keV in mirror nuclei

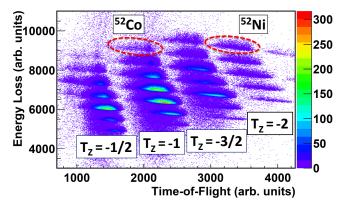


FIG. 2: ΔE versus ToF identification plot for the dataset optimized for 48 Fe. The positions of 52 Co and 52 Ni are shown.

with $T_z=+1/2,-1/2,+1,-1$. MED data for 2^+ states in the A=42-54 region [17] shows that our uncertainty is realistic and conservative. No γ -ray was observed from the 378 keV level, which is expected to be an isomeric state. This is not surprising since the 52 Co, 2^+ level can decay by a Fermi β transition, in contrast with its homologous state in the mirror nucleus. In 52 Mn the Fermi transition is not possible and this, together with the smaller Q_{β} -value, makes the β decay much slower and the slow E4 transition can compete with it.

To detect the population of the ⁵²Co, 6⁺ ground state would require the observation of four γ -rays in cascade (1329, 1942, 1535 and 849 keV) de-exciting the 6^+ IAS in 52 Fe [8], see Fig. 3(b). In contrast the β decay of the expected ⁵²Co, 2⁺ isomer should proceed to its IAS with 2 units of Fermi strength, and to a series of 1⁺, 2⁺ and 3⁺ levels via GT transitions. Since there is no known 1⁺ or 3⁺ level below 6 MeV excitation energy in ⁵²Fe, one can expect to observe the feeding to the IAS and some other 2⁺ states. As discussed in Ref. [8], the most intense γ -ray should be the 849 keV line $(2^+ \to 0^+)$, which is also emitted in the cascade de-exciting the 6⁺ IAS in 52 Fe. The specific signature of 52m Co (2^+) should be the strong population of the IAS, with the observation of its de-exciting γ -rays. In addition, in Ref. [8] it is proposed that the observation of a weak γ -ray at 1910 keV, belonging to a $2^+ \rightarrow 2^+$ transition between the 2759 and 849 keV levels, should also be a typical feature of the population of 52m Co.

Ref. [18] reports two 2⁺ levels in ⁵²Fe separated in energy by 10 keV only, at 6034(5) and 6044(5) keV, both candidates to be the IAS of the ⁵²Co, 2⁺ isomeric state. If the existence of these 2⁺ levels could be confirmed, they may provide another example of isospin mixing in the IAS. The mixing would be strong because of the very small energy separation. A similar situation has been observed, e.g., in Ref. [4] where the energy separation was of the order of 100 keV.

The γ -ray spectrum observed for the decay chain of 52 Ni is shown in Fig. 4(a). In addition to the 141 keV γ ray mentioned above (for the 2407 keV γ -ray see below) and the 511 keV γ line associated with the annihilation of the positrons emitted in the β decay, two other lines are observed at 849 and 1910 keV [they are also shown in Figs. 4(b) and (c), respectively. The γ -ray seen at 1910 keV corresponds to a $2^+ \rightarrow 2^+$ transition between the 2759 and 849 keV known levels [10] in ⁵²Fe [Fig. 3(a) and it is expected to be seen in the decay of the $^{52}\mathrm{Co},\,2^{+}$ isomer [8]. The 1910 keV $\gamma\text{-ray},$ indeed, cannot be observed in the decay of the ⁵²Co, 6⁺ ground state because it does not populate the 2⁺ state at 2759 keV. Moreover, the population of the 2759 keV state starting from the ⁵²Fe, 4⁺ level at 3584 keV would require the observation of a γ -ray of 825 keV, which we do not see [Fig. 4(b)].

The γ -ray spectrum shown in Fig. 4 (a, b, c) was obtained using the high-amplification electronic chain [12] and it allows the study of γ -rays up to 2 MeV. γ -rays

TABLE I: γ -ray energies E_{γ} , γ intensities I_{γ} relative to 52 Ni implants, and γ intensities normalized to 100 decays from 52m Co (2⁺) (using the intensity of the 141 keV γ -ray).

$E_{\gamma} \text{ (keV)}$	$I_{\gamma} \ (\%) \ (^{52}{\rm Ni})$	$I_{\gamma}/100 \text{ decays } (\%) \ (^{52m}\text{Co})$
849(1)	42(8)	97(26)
1910(1)	5(1)	12(3)
5185(10)	17(4)	39(12)

TABLE II: Results on the β^+ decay of 52m Co (2⁺) to 52 Fe. Excitation energies E_X in 52 Fe, β feedings I_{β} , Fermi B(F) and Gamow-Teller B(GT) transition strengths to the 52 Fe levels.

E_X (keV)	I_{β} (%)	B(F)	B(GT)
849(1)	46(28)		0.06(4)
2759(2)	12(3)		0.05(1)
$6034(5)^a$ - $6044(5)^a$	39(12)	$1.6(5)^{b}$	

 $[\]overline{^a}$ IAS, E_X from Refs. [10, 18].

of higher energy were detected using a low-amplification electronic chain, where a problem was observed during the data analysis consisting in a distortion of the peaks (see Ref. [12] for details). In the γ -ray spectrum obtained with the low-amplification chain, in addition to the 2407 keV γ -ray in 52 Co (good agreement was found in both energy and intensity when compared with values in the literature [12, 20]), a γ -ray was observed at around 5 MeV [Fig. 4(d)]. The energy calibration at high energy was performed using the γ lines observed in the decay of ⁵²Co, 6⁺ (Section IV). This procedure gave an energy of 5185(10) keV for the above γ -ray, which was then attributed to the $2^+ \rightarrow 2^+$ transition between the 2^{+} IAS in 52 Fe (at 6034(5) and/or 6044(5) keV [10, 18], where having one or both states does not change our conclusions) and the 849 keV level [Fig. 3(a)]. A further confirmation comes from the fact that the 5185(10) keV γ -ray was also observed [Fig. 6(c) in Section IV] when selecting events where ⁵²Co was implanted, where one expects an admixture of both ground and isomeric states.

Therefore the observed 5185 keV γ -ray establishes clear evidence of the 2^+ isomer in 52 Co, which is supported by the observed 1910 keV γ line. Together, they constitute the first experimental evidence of the decay of 52m Co (2^+) .

Besides the γ -rays described above, a γ -ray of 2760(1) keV was seen in Ref. [19] and attributed to a $2^+ \to 0^+$ transition between the 2759 keV level and the ground state in 52 Fe. Considering the intensity measured in Ref. [19] for this γ -ray and our low γ -efficiency at that energy, we do not expect to see this γ line in our low-amplification spectrum, and indeed we do not observe it.

The half-life associated with a given γ line is determined from the fit of the correlation-time spectrum gated on that γ line, which was created according to the procedure described in Ref. [12]. The fit performed for the 849

^b Calculated assuming all the strength is Fermi.

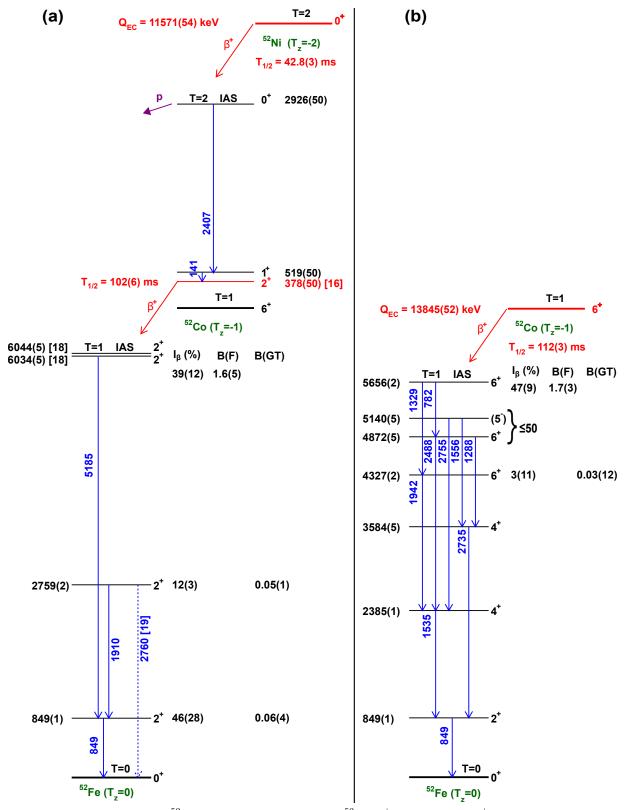


FIG. 3: (a) Partial decay scheme of 52 Ni, including the decay of the 52 Co, 2^+ isomer. Other 1^+ states populated in this decay and de-exciting via proton decay (see Ref. [12]) are not included in the figure. The proton branching of the 52 Co IAS is 25(5)%. The energy of the isomeric level in 52 Co, 378(50) keV, is assumed from the mirror 52 Mn [16]. Two 2^+ levels separated by 10 keV are reported as IAS candidates in 52 Fe [18]. The dashed γ -ray was reported in the literature [19] but not seen in the present work. The quoted I_{β} branchings refer to 100 decays from 52m Co (2^+) estimated using the intensity of the 141 keV γ line. (b) Decay scheme of the 52 Co, 6^+ ground state deduced from the results of the present experiment. The quoted I_{β} branchings refer to 100 decays from 52 Co (6^+).

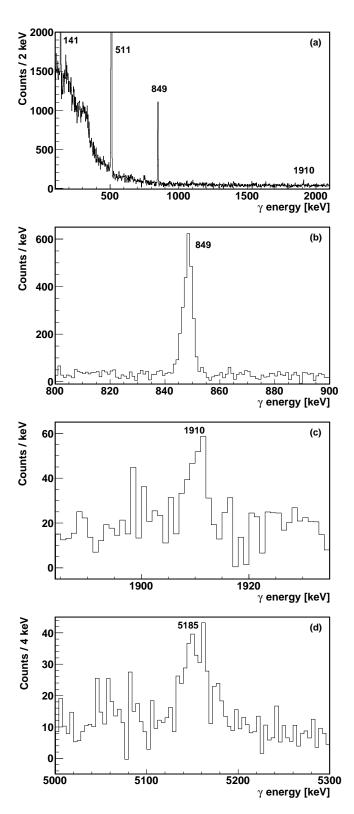


FIG. 4: (a) γ -ray spectrum observed for the decay of 52 Ni. (b) Zoom of the 849 keV γ line. (c) Zoom of the 1910 keV γ line. (d) Zoom of the 5185 keV γ line, detected using the low-amplification electronic chain (see text). The energy given for the peak includes the calibration made with the γ lines from the decay of 52 Co (6⁺).

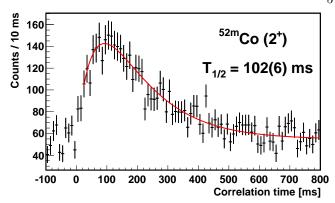


FIG. 5: Fit of the correlation-time spectrum gated on the 849 keV γ line, giving a $T_{1/2} = 102(6)$ ms for the 52 Co, 2^+ isomer.

keV γ line is shown in Fig. 5. The fit function includes the decay of the parent nucleus (52 Ni, with a known half-life of 42.8(3) ms [12], which was kept fixed), the growth of the daughter activity (52m Co, of unknown half-life) and a constant background. From this fit we obtained a half-life of 102(6) ms for 52m Co (2⁺). The much lower statistics prevented us from extracting the half-lives associated with the 1910 and 5185 keV γ -rays when selecting 52 Ni implants. However, by selecting events where 52 Co was implanted we were able to extract a half-life of 91(15) ms for the 5185 keV γ -ray, in agreement with the value quoted above.

The results are summarized in the decay scheme shown in Fig. 3(a) and in Tables I and II. The value $Q_{\beta}=11571(54)$ keV, given in Fig. 3(a) for the decay of 52 Ni, was determined as explained in Section V of Ref. [12], where we deduced the ground state mass excesses for 52 Ni and 52 Co. Adding to that information the measured mass excess for 52 Fe, -48332(7) keV [21], we can determine a value $Q_{\beta}=13845(52)$ keV for the decay of the 52 Co ground state, given in Fig. 3(b).

Table I gives the energies E_{γ} and intensities I_{γ} of the observed γ peaks (both relative to $^{52}\mathrm{Ni}$ implants and normalized to 100 decays from $^{52m}\mathrm{Co}$). The γ intensities relative to $^{52}\mathrm{Ni}$ implants are determined as in Ref. [12]. The γ -efficiency calibration, shown in Fig. 8 of Ref. [12], has been extended to higher γ energies by Monte Carlo simulations. Since the $^{52}\mathrm{Co}$ γ -ray at 141 keV only populates $^{52m}\mathrm{Co}$ (2⁺) and its intensity is 43(8)%, the γ intensities can be normalized to 100 decays from $^{52m}\mathrm{Co}$ using the intensity of the 141 keV γ -ray.

Table II gives the β feedings I_{β} and the Fermi and Gamow-Teller transition strengths for the β -decay of the 52 Co, 2^+ isomer to 52 Fe. The β feedings to the levels populated in 52 Fe are deduced from the γ intensities for 100 decays from 52m Co (2^+). As discussed above, there are two possible candidate levels in 52 Fe (at 6034(5) and 6044(5) keV [10, 18]) for the IAS of 52m Co (2^+), which are expected to be strongly mixed. Unfortunately the resolution of our low-amplification γ spectrum did not allow the disentanglement of the two contributions based on the 5185 keV peak [Fig. 4(d)]. Moreover, in the pop-

ulation of the IAS, both Fermi and Gamow-Teller contributions are possible. Thus we have calculated an upper limit to $B({\rm F})$ assuming all the strength is due to the Fermi transition and taking an average excitation energy of 6039(7) keV. A maximum $B({\rm F})$ of 1.6(5) is obtained, in agreement with the expected value |N-Z|=2. This confirms that the intensity extracted for the 5185 keV γ -ray is meaningful, even with the peak distortion.

IV. HALF-LIFE OF THE ⁵²CO, 6⁺ GROUND STATE

In the same experiment ⁵²Co fragments were also produced directly. This enabled us to add new information on the β decay of the 52 Co 6^+ ground state and measure its half-life with improved precision. In order to study the β decay of the ground state, we have selected the events where ⁵²Co was implanted (see Figs. 1 and 2). They should be a mixture of the ground and isomeric states. The high-amplification γ -ray spectrum obtained for the decay of 52 Co is shown in Fig. 6(a). There, we observed known γ -rays (at 849, 1288, 1329, 1535, 1556 and 1942 keV) [10], expected from the decay of the levels populated in 52 Fe, and a further γ -ray at 782 keV. In the low-amplification spectrum [Fig. 6(b)] we saw in addition other expected γ -rays from ⁵²Fe (at 2488, 2735 and 2755 keV). In the latter spectrum we also observed the 5185(10) keV γ -ray from the decay of 52m Co (2^+) [Fig.

The β decay of the $^{52}\mathrm{Co}$, 6^+ ground state is summarized in Fig. 3(b), where β feeding is expected to the 5⁺, 6⁺ and 7⁺ levels in $^{52}\mathrm{Fe}$. The 6⁺ IAS at 5656 keV [10] in $^{52}\mathrm{Fe}$ de-excites by γ -ray cascades starting with the 782 and 1329 keV γ -rays. A possible 516 keV γ -ray connecting the IAS and the 5140 keV level would be hidden below the 511 keV annihilation peak.

We have observed two γ -rays at 1556 and 2755 keV. corresponding to the de-excitation of the level at 5140(5) keV. A level at 5134(8) keV was observed in Ref. [18], where a $J^{\pi} = 5^{-}$ was attributed to it. In Ref. [19] a level was seen at 5138(4) keV, de-exciting by two γ -rays of 2380 and 4286 keV which we do not observe. Finally, in Ref. [22] a level was observed at 5137 keV, de-exciting by three γ -rays of 740.6, 1553 and 2753 keV. The last two γ -ray energies agree marginally with our observed γ -rays at 1556 and 2755 keV, however we did not observe the 740.6 keV γ -ray, which is supposed to be stronger than the 1553 keV γ line according to Ref. [22]. We believe we see the same level as in Ref. [22], and not the level reported in Ref. [19]. We also do not know if the level we observed corresponds to that in Ref. [18], consequently we have put the 5⁻ assignment in parenthesis in Fig. 3(b).

Table III gives the energies E_{γ} of the observed γ peaks (first column) and their intensities I_{γ} normalized to the 849 keV γ -ray (second column). We could not extract the intensities for the γ -rays above 2 MeV, only observed

in the low-amplification spectrum affected by the peak distortion. We obtained the intensity of the 2735 keV γ -ray by summing those of the 1288 and 1556 keV γ -rays, i.e., we assumed that the 3584 keV level is not directly populated in either the β decay of the 6^+ ground state or the β decay of the 2^+ isomeric level.

Looking at the intensities normalized to that of the 849 keV γ -ray, we get 24(6)% and 27(7)% for the 1329 and 1942 keV γ -rays, respectively. Within the errors, a small amount of β feeding to the 4327 keV level is possible. In Ref. [8] the intensity of the 1942 keV γ -ray was reported to be 17% lower than that of the 1329 keV γ -ray. This was probably because the 1942 keV peak was not resolved from a 1944 keV peak from the decay of $^{50m}\mathrm{Mn}$.

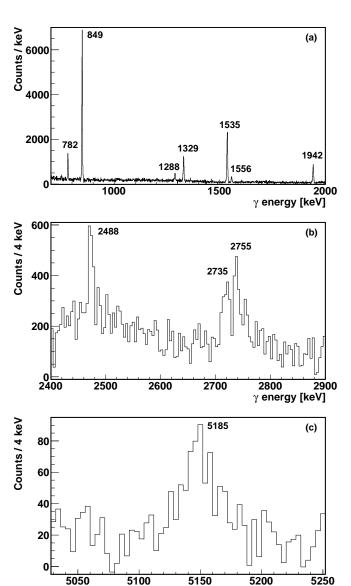


FIG. 6: (a) γ -ray spectrum observed for the decay of $^{52}\mathrm{Co}$ with the high-amplification electronic chain. (b) and (c) Zoom of the low-amplification spectrum in the regions of interest.

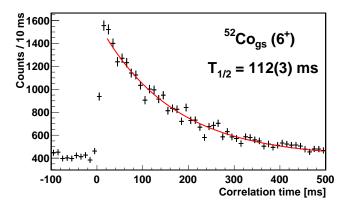


FIG. 7: Fit of the correlation-time spectrum obtained as a sum of the spectra gated on the 1329, 1535 and 1942 keV γ -rays from the decay of the 52 Co, 6^+ ground state, giving a $T_{1/2} = 112(3)$ ms.

TABLE III: Column one shows the γ -ray energies E_{γ} . Column two gives the γ intensities I_{γ} relative to the 849 keV γ -ray, including both the 6⁺ and the 2⁺ 52 Co decays. Column three presents the γ intensities normalized to 100 decays from the 52 Co (6⁺) ground state.

$E_{\gamma} \; (\text{keV})$	$I_{\gamma}/I_{\gamma}(849) \ (\%)$	$I_{\gamma}/100 \text{ decays } (\%) (^{52}\text{Co}_{gs})$
782(1)	15(4)	18(5)
849(1)	100(26)	100(21)
1288(1)	8(2)	10(3)
1329(1)	24(6)	29(8)
1535(1)	67(17)	81(21)
1556(1)	7(2)	9(2)
1942(1)	27(7)	32(8)
2488(5)		
2735(5)	16(3)	19(3)
2755(5)		

The summed intensities of the 1535 and 2735 keV γ rays, which both go to the 849 keV level, are 83(31)%. This means that the 2⁺ level at 849 keV may have an extra feeding of 17(31)% that may be attributed to the β decay of the ⁵²Co (2⁺) isomeric state. With this information one can normalize the γ intensities to 100 decays from the ⁵²Co (6⁺) ground state; these values are presented in the third column of Table III. They are also used to calculate the β feedings shown in the second column of Table IV. We expect that the levels at 4872 and 5140 keV get some direct feeding, which we cannot estimate because we miss the intensities of the 2488 and 2755 keV γ -rays. Thus we attribute the missing β feeding (50%) to these 4872 and 5140 keV levels. Besides the β feedings, Table IV gives B(F) and B(GT). Also in this case both Fermi and Gamow-Teller contributions are possible in the population of the IAS, thus we calculated an upper limit to B(F). We obtained a maximum B(F)of 1.7(3), which agrees with the expected value |N-Z|= 2.

TABLE IV: Results on the β^+ decay of the 52 Co (6⁺) ground state to 52 Fe. Excitation energies E_X in 52 Fe, β feedings I_{β} , Fermi B(F) and Gamow-Teller B(GT) transition strengths to the 52 Fe levels.

$E_X \text{ (keV)}$	I_{β} (%)	B(F)	B(GT)
849(1)			
2385(1)			
3584(5)			
4327(2)	3(11)		0.03(12)
4872(5)	≤ 50		
5140(5)	\(\sigma_{00} \)		
$5656(2)^a$	47(9)	$1.7(3)^b$	

 $[\]overline{^a}$ IAS.

As mentioned above, in fragmentation experiments both the 6^+ ground state and the 2^+ isomer will be implanted together and cannot be separated with the available information on the implants. This has to be taken into account in the determination of the half-life of the ⁵²Co ground state. In Ref. [8], indeed, because of the ambiguity of the origin of the 849 keV γ -rays their apparent half-life [104(11) ms] was not used to determine the half-life of the 52 Co ground state $[T_{1/2} = 115(23)]$ ms]. More recently, the β decay of ⁵²Co was revisited in Ref. [23] and a value of 103(7) ms was extracted for the half-life of the ground state by gating on the β particles. Combining this with the previous measurement [8] gives a weighted average value of 104(7) ms which is the value reported in the most recent compilation for mass A = 52[10]. However, in Ref. [23] the possible implantation of the ⁵²Co isomer together with the ⁵²Co ground state was not considered.

To determine the half-life of the $^{52}\mathrm{Co},\,6^+$ ground state in a isomer-free way, we have constructed a correlation-time spectrum as the sum of the spectra gated on the 1329, 1535 and 1942 keV γ -rays. The fit to this spectrum, shown in Fig. 7, gives $T_{1/2}=112(3)$ ms. This result agrees with the value from Ref. [8] but the precision is improved.

V. CONCLUSIONS

We reported the first experimental observation of the decay of the 2^+ isomeric state in $^{52}\mathrm{Co}$, which was produced in the β decay of $^{52}\mathrm{Ni}$. We observed the decay of $^{52m}\mathrm{Co}$ to $^{52}\mathrm{Fe}$, where it populates various 2^+ states including the IAS. These 2^+ levels then de-excite by γ -ray emission and we observed three γ -rays at 849, 1910 and 5185 keV. The observed de-excitation of the IAS (by the 5185 keV γ -ray) is clear evidence of the population of the 2^+ isomer, which is reinforced by the observation of the expected [8] γ -ray at 1910 keV. The β feedings for the decay of the $^{52}\mathrm{Co}$ isomer to the 2^+ levels in $^{52}\mathrm{Fe}$ and the

^b Calculated assuming all the strength is Fermi.

Fermi and Gamow-Teller transition strengths have been determined. We have extracted a half-life of 102(6) ms for the 52 Co, 2^+ isomer using the 849 keV γ line.

We have also studied the β decay of the 52 Co, 6^+ ground state by gating on the events where ⁵²Co was implanted, obtaining new information. Many γ -rays were observed, including a previously unobserved γ -ray at 782 keV, and their intensities were determined. The β feedings for the decay of ⁵²Co (6⁺) to the 6⁺ levels in ⁵²Fe and the B(F) and B(GT) were deduced. A half-life of 112(3) ms was measured for the ⁵²Co (6⁺) ground state, improving the uncertainty in comparison with the values reported in the literature.

The 52 Co nucleus lies in the rp-process pathway, where the proton-absorption and β -decay processes compete. Hence the existence of a β -decaying isomer as well as its decay properties are important.

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