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Beta-delayed γ and neutron emission near the double shell closure at ^{78}Ni

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Abstract. An experiment was performed at the National Superconducting Cyclotron Laboratory at Michigan State University to investigate β decay of very neutron-rich cobalt isotopes. Beta-delayed neutron emission from $^{71-74}$Co has been observed for the first time. Preliminary results are reported.

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Nuclear structure in the vicinity of the double shell closure at $Z = 28$, $N = 50$ has garnered increasing interest in recent years [1,2,3,4,5,6,7]. The large neutron excess in this region is expected to affect the nucleon-nucleon interaction and lead to new phenomena as changes to the traditional shell gaps and magic numbers [8]. These nuclei are relevant to nuclear astrophysics as they are believed to take part in nucleosynthesis near the origin of the r-process [9]. Beta-delayed neutron (βn) emission close to ^{78}Ni is of particular interest as its investigation can reveal information on the Gamow-Teller β-strength distribution and on decay branching ratios. These observables are astrophysically-important, serving as input parameters to r-process network calculations. Several experimental studies have been performed for nuclei approaching ^{78}Ni [2,3,4,5,6] and a new theoretical description was recently developed [7]. In the present contribution we report on preliminary results from the investigation of the decay of neutron-rich Co isotopes.

The experiment was performed at the National Superconducting Cyclotron Laboratory at Michigan State University. The nuclides studied were produced by fragmentation of a 140 $A \cdot$MeV ^{86}Kr beam in a ^{9}Be target, separated using the A1900 spectrometer [10] and implanted into a 1.5 mm thick double-sided silicon strip detector (DSSD) positioned within a silicon detector telescope [11]. Ion implants and their subsequent β decays were observed in this detector and correlated in software. Time correlations were allowed between the implanted ion and electrons detected in the pixel itself or in any neighboring pixel. The detection correlation efficiency was $\sim 30\%$. The correlation time was selected to be $\sim$ 4–5 times the decay half-life. The implantation detector was surrounded by 12 detectors from the MSU Segmented Germanium Array (SeGA) [12] to enable observation of both implant- and decay-coincident γ-rays. The total photopeak detection efficiency of the SeGA was 4.6% at 1.3 MeV. Two different ion-optics settings of the A1900 spectrometer, optimized for transmission of ^{72}Co and ^{74}Co were used during the measurement in order to maximize the rate at the counting station for the fragments of interest.

An analysis of β-delayed γ-rays ($\beta\gamma$) from decay events correlated with $^{71-74}$Co implantation events has confirmed the decay half-lives of $^{71-74}$Co and the known transitions in $^{71-73}$Ni [13] and provided the first spectroscopic information on ^{74}Ni [14]. The first evidence for β-delayed neutron emission from very neutron-rich cobalt isotopes has also been obtained. The correlated $\beta\gamma$ spectra show not only transitions previously assigned to the β-decay daughter, but also transitions within the βn daughter.

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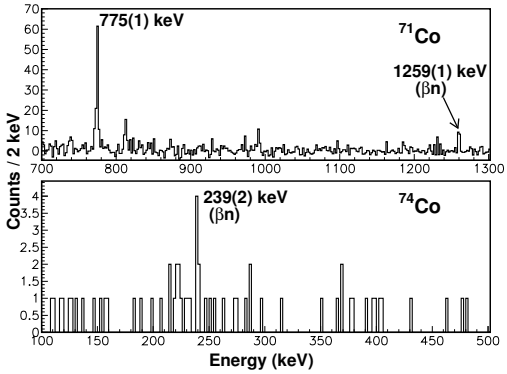

Fig. 1. Background-subtracted β-coincident γ-ray spectra of ^{71}Co decay between 700 and 1300 keV (upper panel) and of ^{74}Co decay between 100 and 500 keV (lower panel) showing the evidence for βn emission.

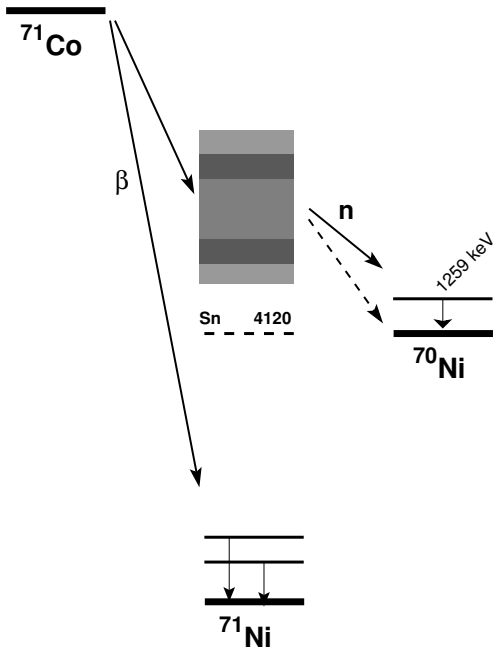

Fig. 2. Schematic representation of the decay mechanism studied in this work for the case of ^{71}Co. Observed decay channels are shown as solid lines, while βn emission to the ground state, unobserved in this measurement, is shown as a dashed line. The neutron separation energy (S_n) in ^{71}Ni is also marked as a dashed line and its value ([15]) is expressed in keV.

A 1259 keV line from the $(2^+) \rightarrow 0^+$ transition in ^{70}Ni [2] is clearly identified in the ^{71}Co decay spectrum, while a 239 keV transition in ^{73}Ni [13] is observed in the decay spectrum of ^{74}Co (fig. 1). Similarly, a 566 keV γ line from a low-lying transition in ^{71}Ni [13] and a 1096 keV line from the $(2^+) \rightarrow 0^+$ decay in ^{72}Ni [3] are identified in the decay spectra of ^{72}Co and ^{73}Co, respectively. These γ-rays are hallmarks of the βn decay mechanism, which is shown for the case of ^{71}Co in fig. 2. Beta-delayed neutron emission is expected on the basis of the large Q-values —several MeV in each case— from mass systematics [15] and theoretical predictions [16]. From the number of counts observed in the β- and in the βn-delayed γ-ray peaks, corrected for efficiency and intensity, preliminary lower limits for the βn branching ratios have been determined, see table 1. Evidence for ground-state feeding of the βn daughter was also obtained from the observation of granddaughter activity, the data are currently being evaluated.

In summary, we have investigated the β decay of $^{71-74}$Co. Beta-delayed γ-rays were observed and the half-lives measured, confirming previously reported results from the decay of $^{71-73}$Co [13] with improved statistics and providing the first spectroscopic information on ^{74}Co [14]. Moreover, the first evidence for βn from these nuclei was obtained. Further analysis of the data is in progress.

Table 1. Compilation of Q-values for β decay (Q_β) and βn decay ($Q_{\beta n}$) from systematics [15] and mass predictions [16] for $^{71-74}$Co. Predicted branching ratios for βn emission ($b_{\beta n}$) [16] are also given in comparison with the preliminary lower limits from this measurement. The number of collected ions and measuring time are also reported for each isotope.

Nucleus Ions (hours)	Q_β (MeV)	$Q_{\beta n}$ (MeV)	$b_{\beta n}$ (%)	Ref.	$b_{\beta n}$ (exp) (%)
^{71}Co	11.33(92)	7.21(91)	–	[15]	$\geq 3(1)$
46675 (27)	10.82	6.89	2.61	[16]	
^{72}Co	14.64(74)	7.83(70)	–	[15]	$\geq 6(2)$
11733 (27)	13.98	7.04	4.80	[16]	
^{73}Co	12.83(76)	8.83(82)	–	[15]	$\geq 9(4)$
3442 (68)	12.26	8.29	4.82	[16]	
^{74}Co	16.12(90)	9.54(86)	–	[15]	$\geq 26(9)$
482 (68)	15.50	9.01	6.90	[16]	

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