

# New isotope $^{184}\text{Bi}$ and decay spectroscopy of $^{185,186,188,190}\text{Bi}$

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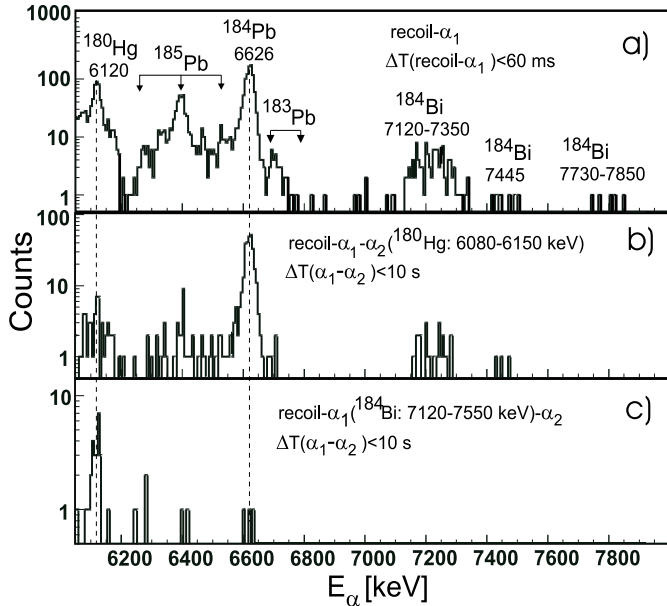


Figure 1: Data obtained in the  $^{93}\text{Nb}(^{94}\text{Mo},3n)^{184}\text{Bi}$  reaction at  $E_{\text{lab}}(^{94}\text{Mo})=444$  MeV in front of the target. Part a) shows  $\alpha_1$  decays recorded in the PSSD between the beam pulses and correlated with recoils within 60 ms. Part b) shows a spectrum of  $\alpha_1$  decays from the recoil- $^{184}\text{Bi}$   $\alpha_1 \rightarrow ^{180}\text{Tl} \xrightarrow{\beta^+/\text{EC}} ^{180}\text{Hg} \xrightarrow{\alpha_2} ^{176}\text{Pt}$  analysis with a condition that the recoil- $\alpha_1$  events from a) are further correlated within 10 s with the 6120 keV decay of  $^{180}\text{Hg}$ , being the daughter of  $^{180}\text{Tl}$  after its dominant  $\beta^+/\text{EC}$  decay; Part c) shows a spectrum of  $\alpha_2$  decays from the [recoil- $\alpha_1(^{184}\text{Bi})$ ]- $\alpha_2$  analysis, with a gate on the  $E_{\alpha_1}=7120\text{-}7550$  keV region of fig. 1a.

The new nuclide  $^{184}\text{Bi}$  was identified and decay properties of the neutron-deficient  $^{185,186,188,190}\text{Bi}$  isotopes were re-studied in detail in experiments at the velocity filter SHIP. To produce  $^{184-186}\text{Bi}$  nuclei the  $2n,3n$ - channels of the symmetric reactions  $^{94,95}\text{Mo}+^{93}\text{Nb} \rightarrow ^{187,188}\text{Bi}^*$  were used, while the pxn- channel of the  $^{50,52}\text{Cr}+^{142}\text{Nd} \rightarrow ^{192,194}\text{Po}^*$  reactions was exploited to study  $^{188,190}\text{Bi}$ . The evaporation residues were separated in-flight and subsequently identified on the basis of the recoil- $\alpha$ , recoil- $\alpha$ - $\alpha$  and recoil- $\alpha$ - $\gamma$  analysis and excitation function measurements.

## $^{184}\text{Bi}$

Fig. 1 shows spectra used for the identification of  $^{184}\text{Bi}$ , to which three groups of  $\alpha$  decays at about 7120-7350 keV, 7445(25) keV and at 7730-7850 keV were assigned (see Fig.1a). They were attributed to the decays of two iso-

meric states in  $^{184}\text{Bi}$  with half-lives of  $T_{1/2}=13(2)$  ms and 6.5(1.5) ms (see table 1). The  $\alpha$  branching ratio of the daughter  $^{180}\text{Tl}$  nucleus was deduced for the first time as  $b_{\alpha}(^{180}\text{Tl})=(2-12)\%$ . Full discussion of the data will be given in [1].

## $^{185}\text{Bi}$

The particle ( $\alpha$  and proton) decay of  $^{185}\text{Bi}$  was previously studied by Davids et al. [2] and Poli et al. [3]. In total a few tens of proton and  $\alpha$  decays were observed (deduced proton branching ratio  $b_p=85(6)\%$  [3]), which were attributed to the decay of the  $1/2^+$  oblate intruder state. The observation of only one isomeric state in  $^{185}\text{Bi}$  was in contrast to the decay of all heavier odd-mass  $^{187-207}\text{Bi}$  nuclei in which two long-lived isomeric states are known: a nearly spherical  $9/2^-$  ground state coexisting with an excited oblate intruder  $1/2^+$  state.

In order to search for the decay of a possible second isomeric state and to improve statistical uncertainty of the previous measurements we re-investigated the decay of  $^{185}\text{Bi}$ . In our experiment the statistics was increased by about one order of magnitude within about half the beam time as compared to [3]. The spectrum of proton decays of  $^{185}\text{Bi}$  obtained in our work is shown in Fig.2. The data analysis is in progress.

By correlating the proton decays of  $^{185}\text{Bi}$  with the known 6626 keV  $\alpha$  decay of the daughter nucleus  $^{184}\text{Pb}$  an  $\alpha$ -branching ratio of  $b_{\alpha}(^{184}\text{Pb})=80(15)\%$  was deduced, which is in disagreement with the value of  $b_{\alpha}(^{184}\text{Pb})=23(14)\%$  from [3]. The reduced  $\alpha$  width  $\delta_{\alpha}^2(^{184}\text{Pb})=48(10)$  keV, deduced from our data using the Rasmussen formalism [4], fits well to the systematics of reduced widths for the neighbouring even-even Pb nuclei. In contrast, the value of  $\delta_{\alpha}^2(^{184}\text{Pb})=13(8)$  keV from [3] results in an unexpected kink in the otherwise smooth reduced  $\alpha$ -width systematics.

## $^{186}\text{Bi}$

To produce  $^{186}\text{Bi}$  nuclei a  $^{93}\text{Nb}(^{95}\text{Mo},2n)^{186}\text{Bi}$  reaction at  $E_{\text{lab}}(^{95}\text{Mo})=419$  MeV was used. The total number of  $^{186}\text{Bi}$  nuclei collected was at least fifty times higher than in the previous works [5, 6]. Along with the possibility of measuring  $\alpha$ - $\gamma$  coincidences and excitation functions this allowed us to perform a more detailed study of this nucleus (see table 1). As in the heavier odd-odd  $^{188-196}\text{Bi}$  isotopes, the existence of two  $\alpha$ -decaying isomeric states with tentative spin and parity assignments of  $(10^-)$  and  $(3^+)$  was confirmed. A number of new  $\gamma$  transitions in the daughter isotope  $^{182}\text{Tl}$  were observed. Partial data are reported in this contribution, while the full account will be given in [1].

Table 1: Summary of our results on  $^{184,186}\text{Bi}$ . For  $^{186}\text{Bi}$  the previous data from [6] are also shown. Column 1 shows the final half-life of each isomer, deduced from our work, while the values for each individual decay (where deduced) are shown in column 3. The uncertainty of the  $\gamma$ -energy values is 1 keV.

Our Data				Ref. [6]	
Assignment , $T_{1/2}$ , $I^\pi$	$E_\alpha$	$T_{1/2}$	Coincident $\gamma$ 's	$E_\alpha$	$T_{1/2}$
	keV	ms		keV	keV
$^{186m1}\text{Bi}$ , 9.8(4) ms , ( $10^-$ )	7263(5) 7369(10)	9.8(4)	108.5(5) E1	7261(20)	9.8(13)
$^{186m2}\text{Bi}$ , 14.8(8) ms, ( $3^+$ )	7070-7230 <sup>a</sup>	14.8(8)	87, 98, 133, 215, 238, 276, 281, 371, 380, 444, 520	7158(20)	15.0(17)
	7080(15)		520		
	7120(15)		133		
	7152(15)		444		
$^{184m1}\text{Bi}$ , 13(2) ms	7226(15)	13(2)	238		
	7120-7350 <sup>b</sup>		124		
	7194(20)		14 <sup>+6</sup> <sub>-4</sub>		
	$^{184m2}\text{Bi}$ , 6.6(1.5) ms <sup>c</sup>		449		
	7220(15)	4.6 <sup>+1.9</sup> <sub>-1.3</sub>			
	7445(25)	8.1 <sup>+3.0</sup> <sub>-2.2</sub>			
	7730-7850	6.7 <sup>+3.0</sup> <sub>-2.2</sub>			

<sup>a</sup> - complex structure with contributions from many  $\alpha$  decays. The next four lines show the  $\alpha$  decays with a well-defined  $\alpha$ -decay energy only. Due to uncertainty in the half-life determination these decays may belong to different isomers in  $^{186}\text{Bi}$ . They are shown in Table 1 separately only to provide information on the  $\alpha$ - $\gamma$  coincidence relations.

<sup>b</sup> - complex structure with contributions from many  $\alpha$  decays.

<sup>c</sup> - based on the summed statistics for the shorter-lived groups at 7445(25) keV, 7730-7850 keV and 7220(15)-449(1) keV

## 188,190Bi

Based on  $\alpha$ - $\gamma$  coincidence relations considerably improved data on the fine structure  $\alpha$  decays of  $^{188,190}\text{Bi}$  were obtained. For both of these nuclei a total number of  $\alpha$  decays observed was about two orders of magnitude greater compared to previous work [7]. In particular, a ( $10^-$ ) isomeric state, being presumably a member of the  $[\pi 1h_{9/2} \times \nu 1i_{13/2}]_{2^- - 11^-}$  proton-neutron multiplet was identified in  $^{184}\text{Tl}$ . The excitation energy of the state fits well to the systematics of  $10^-$  intruder states in the heavier odd-odd mass Tl nuclei. Full account of the data will be given in [8].

## References

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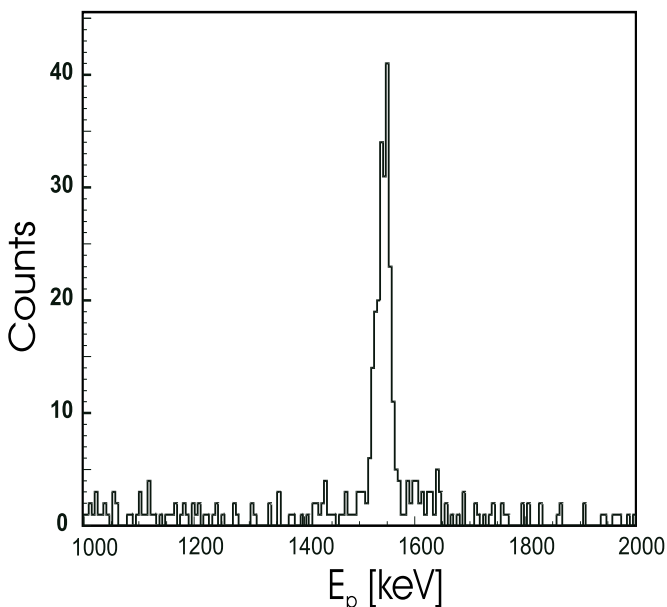


Figure 2: Proton spectrum measured in the  $^{93}\text{Nb}(^{95}\text{Mo},3n)^{185}\text{Bi}$  reaction. Shown are the proton decays recorded in the PSSD and correlated with recoils within 300  $\mu\text{s}$  after implantation.