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Improved experimental determination of the branching ratio for β -delayed α decay of ^{16}N

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Abstract. We report on the preliminary results of an experimental study of the β decay of ^{16}N , aiming to determine the branching ratio of the $\beta\alpha$ channel with a precision of $\leq 5\%$.

1 Introduction

During hydrostatic helium burning carbon is converted to oxygen via the reaction $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$. The temperature at which this takes place is $T \sim 10^8$ K, implying that reactions preferentially occur close to a center-of-mass energy of $E_{\text{cm}} \sim 0.3$ MeV. At such low energies the cross section is too small to be measured directly in laboratory experiments and must be determined by extrapolating the data obtained at higher energies ($E_{\text{cm}} \gtrsim 1.0$ MeV). Typically, R -matrix theory [1] is used to parametrize the, a priori unknown, energy dependence of the cross section in terms of the properties of the levels in ^{16}O that are involved in the reaction. Since the same levels can be observed in other reactions many of the relevant parameters can be accurately determined or at least constrained by indirect techniques. Following this approach the cross section at 0.3 MeV has been determined with an estimated precision of $\sim 20\%$ while a precision of at least $\sim 10\%$ is desired [2]. Among the indirect techniques used the β -delayed α decay of ^{16}N , shown in Fig. 1, has proven useful to determine how strongly the 7.12 MeV level in ^{16}O couples to the $\alpha + ^{12}\text{C}$ channel, and hence constrain the level's significant contribution ($\sim 54\%$) to the capture cross section at 0.3 MeV. This requires precise measurements of the branching ratio to the 7.12 MeV level, the branching ratio for α emission, and the shape of the α spectrum. Here, we bring the preliminary results of a new experimental study of the β decay of ^{16}N recently performed at the ISOLDE facility [3] with the aim of obtaining precise values for the branching ratios.

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3 New experiment and preliminary results

In order to close some of the gaps in our knowledge about the β decay of ^{16}N , we have studied the decay at ISOLDE [3]. In this study, performed in May 2016, a 30 keV beam of $^{14}\text{N}^{16}\text{N}^+$ molecular ions was delivered to the ISOLDE Decay Station (IDS) [12] at an average rate of $\sim 2 \times 10^4 \text{ s}^{-1}$ for a total of 32 hours. The ions were stopped in a thin ($30 \mu\text{g}/\text{cm}^2$) carbon foil surrounded by five double-sided silicon strip detectors (DSSD) and four high-purity germanium (HPGe) clovers, allowing for the simultaneous detection of charged particles and γ rays, while auxiliary detectors were used to check that the beam was being fully transmitted to the center of the setup and fully stopped in the foil. Three of the DSSDs were sufficiently thin ($40\text{--}60 \mu\text{m}$) to allow the α spectrum to be clearly separated from the β background, as shown in Fig. 2. The other two DSSDs were much thicker ($300 \mu\text{m}$ and 1 mm)

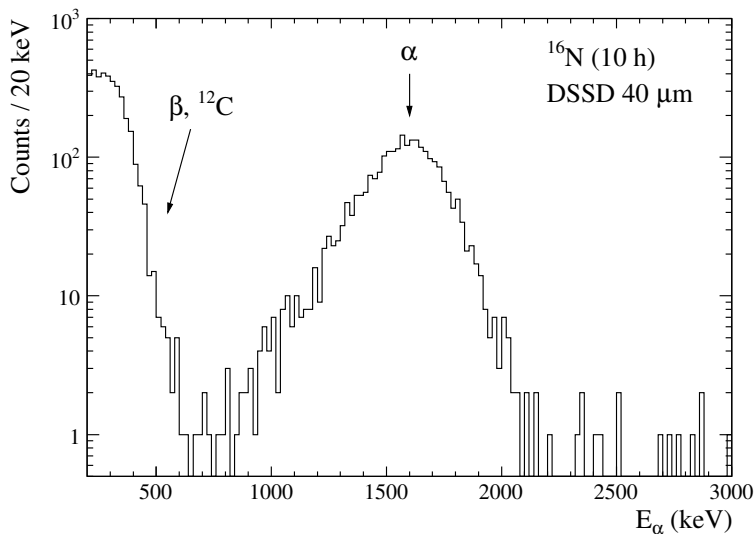


Figure 2. Energy spectrum measured in the $40\text{-}\mu\text{m}$ thick DSSD. The α particles emitted in the decay of ^{16}N have energies between 0.8 MeV and 2.2 MeV and are seen to be well separated from the β particles and the ^{12}C recoils. The data shown here represents $1/3$ of the total acquired data. The remaining data have yet to be analyzed.

and served primarily to detect the β particles. The γ -ray spectrum measured in the HPGe clovers (Fig. 3) contains several γ -rays from the decay of ^{16}N with no evidence of other radioactive isotopes. In order to convert the observed γ -ray yields to intensity ratios it is necessary to correct for the energy dependent detection efficiency of the HPGe array. An absolutely calibrated ^{152}Eu source was used to determine the detection efficiency at low energies ($E_\gamma < 1.5 \text{ MeV}$), while $\beta\gamma$ and $\gamma\gamma$ coincidences will be used to extend the calibration up to 7 MeV .

4 Summary and outlook

The β decay of ^{16}N has been studied in an experiment at the ISOLDE Decay Station in which both charged particles and γ rays were detected. It is expected that the data will constrain the branching ratio for β -delayed α emission and the branching ratio to the 7.12 MeV level with a precision of 5% or better. The data analysis is nearing completion and the results will soon be published, including an assessment of the impact on the inferred cross section of the $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reaction at $E_{\text{cm}} = 0.3 \text{ MeV}$.

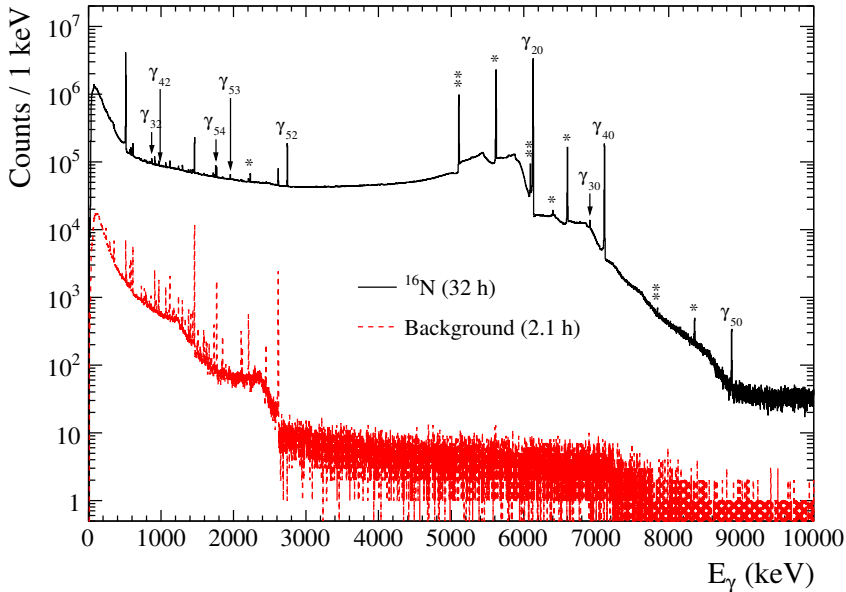


Figure 3. Add-back γ -ray spectrum obtained in the present experiment. ^{16}N : solid (black) line. Background: dashed (red) line. Photopeaks due to transitions $i \rightarrow j$ in ^{16}O are indicated by the symbol γ_{ij} while first- and second-escape peaks are indicated by a single asterisk (*) and a double asterisk (**), respectively.

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