Probing the Nuclear Structure of ^{116}Cs Through Proton-Unbound States and Gamma Spectroscopy

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Introduction

The nucleus ^{116}Cs, situated near the proton drip-line may exhibits exotic decay phenomena due to its large Q-value(Q_{EC}=11 MeV). This is an ideal candidate for investigating particle-unbound states, which provide critical insights into nuclear structure, large-scale shell models, nucleon-nucleon (n-n) interactions, and the coupling to the continuum. Furthermore, the study of such nuclei near the endpoint of the rp-process nucleosynthesis is essential for advancing our understanding of nuclear astrophysics. In particular, the identification of previously unobserved proton-unbound states in the daughter nucleus ^{116}Xe, contributes to refining nuclear structure models. In our investigation, we have identified several unbound states in ^{116}Xe, which agree with previously reported higher-energy states[1]. Notably, we have also observed lower-energy unbound states for the first time. Furthermore, a potential resonance state has been discovered just above the proton emission threshold. In addition, a gamma transition from an excited state of ^{116}Xe has been identified, and from the time distribution of this transition, we have calculated the half-life of ^{116}Cs, providing new insights into the decay dynamics of this neutron-deficient nucleus. This study provides valuable data that could influence theoretical models and has potential applications in both nuclear structure and astrophysics.

Experimental Setup

This experiment has been performed by IS545-IDS collaboration at the ISOLDE facility at CERN [2]. Pulses of 1.4 GeV protons from PS Booster impacted on a Lanthanum Carbaide target, then by fragmentation/spallation reaction radioactive beam, ^{116}Cs was produced and separated by mass spectrometer(GPS). This secondary beam was transfered to the experimental hall and implanted on a carbon target. The IDS experimental set-up is described in [3],shown partially in FIG.1.

Data analysis and Spectrum

The raw data were unpacked and calibrated with the help of ROOT framework. For the

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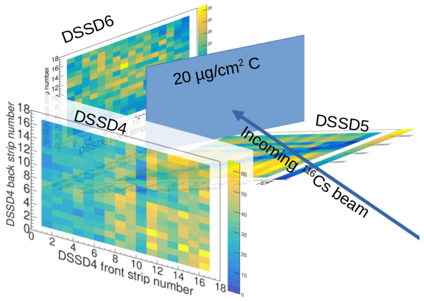

FIG. 1: A two-dimensional hit map for the number of detected counts for DSSD4,DSSD6 and DSSD5 with Multiplicity = 1

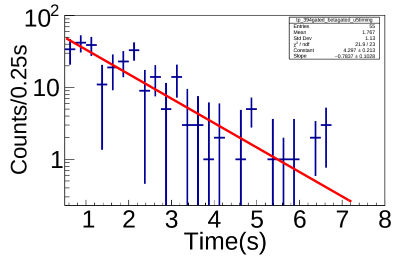

FIG. 2: Time distribution of 394 kev gamma (Time distribution of background of 394 keV gamma has been substructed)

calibration of silicon detectors some standard alpha sources were used which were ^{148}Gd$_{64}$, ^{241}Am$_{95}$, ^{239}Pu$_{94}$, ^{249}Cf$_{98}$. For the calibration of clover a standard gamma source ^{152}Eu was used. After the calibration from E-ΔE spectra one can easily distinguish proton and beta events. High energy proton events have been obtained in thin ΔE-E telescope array. The Low energy protons(less than 2.5 MeV) were stopped by the thin ΔE ($\sim 65\mu m$). The total angular coverage of the charged particle detector array $\sim$ 45.897%.

The half-life of ^{116}Cs was determined from the time-distributed 394 keV gamma line[FIG.2]. The spectrum was fitted with the exponential decay function $N = N_0\ e^{-\lambda t}$, as shown in the figure. The obtained half-life of ^{116}Cs is 0.89(12) s, compared to the previously reported value of 0.70(4) s.

Proton Unbound States of ^{116}Xe

The deposited energies of protons in the thin DSSD and PAD detectors were summed to obtain the delayed proton spectrum for higher energies. Low-energy protons (less than 2.5 MeV) were fully stopped in the thin DSSD, as observed from the thin DSSD spectrum in anticoincidence with the PAD detector. The delayed proton spectrum was fitted by minimum chi-square estimation [FIG.3] to extract the properties of excited states.

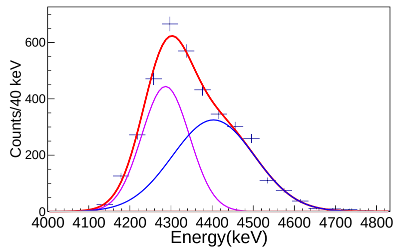

FIG. 3: Proton unbound states of ^{116}Xe just above the proton threshold, reconstructed at center of mass frame

Conclusion

We are exploring the decay properties of the neutron-deficient nucleus ^{116}Cs (S_p = 680 keV). We have identified previously unobserved lower-energy unbound states and a new resonance state of the daughter nucleus (^{116}Xe) above the proton threshold. The half-life of ^{116}Cs is obtained from the time distribution of the 394 keV γ-ray (first excited state of the daughter nucleus), and it is in agreement with the previously reported value[1].

References

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