PROCEEDINGS OF SCIENCE

Measurement of ^{115}In β-decay with ACCESS

Stefano Ghislandi[a,b] **and Lorenzo Pagnanini**[a,b,*]

[a] *Gran Sasso Science Institute,*
Viale Crispi 7, I-67100 L'Aquila, Italy
[b] *INFN - Laboratori Nazionali del Gran Sasso,*
Via Acitelli 22, I-67100 Assergi (AQ), Italy

E-mail: stefano.ghislandi@gssi.it, lorenzo.pagnanini@gssi.it

PoS(NOW2024)059

Current bounds on the neutrino Majorana mass are affected by significant uncertainties in the nuclear calculations for neutrino-less double-β decay. A key issue for a data-driven improvement of the nuclear theory is the actual value of the axial coupling constant g_A, which can be investigated through non-unique forbidden β-decays. The ACCESS (Array of Cryogenic Calorimeters to Evaluate Spectral Shapes) project aims to establish a novel technique to perform precision measurements of forbidden β-decays, which can serve as an important benchmark for nuclear physics calculations and represent a significant background in astroparticle physics experiments. ACCESS will operate a pilot array of cryogenic calorimeters based on natural and doped crystals containing β-emitting radionuclides. In this way, natural (e.g. Cd-113 and In-115) and synthetic isotopes (e.g. Tc-99) will be simultaneously measured with a common experimental technique. Here we present a summary of the first measurement of the fourth-forbidden β-decay of In-115 with a cryogenic calorimeter based on indium iodide. Exploiting the enhanced spectrum-shape method for the first time to this isotope, our study accurately determines simultaneously spectral shape, g_A, and half-life.

12th Neutrino Oscillation Workshop (NOW2024)
2-8, September 2024
Otranto, Lecce, Italy

*Speaker

1. Introduction

The search for neutrino-less double-beta decay (NDBD) is a pivotal effort in understanding the fundamental nature of neutrinos and the evolution of our Universe [1]. Detecting NDBD would challenge the Standard Model of particle physics by revealing that neutrinos are Majorana particles, meaning they are their own antiparticles. This discovery could provide insights into the absolute neutrino mass and indicate a violation of lepton number conservation, which could explain the matter-antimatter asymmetry in the Universe. Current experiments, have set stringent limits on the effective Majorana mass exploiting several isotopes [2–6], but these limits are heavily influenced by uncertainties in Nuclear Matrix Element (NME) calculations. Therefore, improving the predictive ability of nuclear theories is of fundamental importance. Data and physical processes that could help clarify the puzzle include single and double-charge exchange reactions [7], ordinary muon captures [8, 9], two neutrino double beta decays [10, 11], and forbidden non-unique β-decays [12]. In particular, the latter are very interesting to investigate the origins of the quenching of g_A, being the shape of the forbidden non-unique β-decay spectrum highly dependent on the ratio of g_A/g_V.

In this context, several isotopes have been studied such as Cd-113 [13, 14], Tc-99 [15], and In-115 [16] using the so-called spectrum-shape method (SSM) [17]. This theoretical framework matches with high precision the spectral shape of experimental data. However, the simultaneous prediction of the decay half-life is often far from being compatible with the measured values. Improvements of the models in this direction have been done during the last years within the so-called enhanced SSM theory [18], where the small relativistic NME (sNME) enters as an additional parameter, facilitating the adjustment of both partial half-life and spectral shape.

2. The ACCESS project

The ACCESS (Array of Cryogenic Calorimeters to Evaluate Spectral Shape) project seeks to advance the experimental study of forbidden β-decays through a novel approach using cryogenic calorimeters [19, 20]. ACCESS is developing an array of detectors, including natural and doped crystals that host β-emitting isotopes like In-115, Cd-113 and Tc-99.

The ACCESS calorimeters are designed to precisely measure the spectral shape of forbidden β-decays with high sensitivity, exploiting temperature sensors such as Neutron Transmutation Doped (NTD) thermistors and Transition-Edge Sensors (TES). These devices allow the ACCESS project to perform accurate measurements, disentangling β-signal from sources in a low-background environment.

3. Measurement of ^{115}In β-decay with ACCESS

Following the design principles outlined in Ref. [20], we measured an indium iodine crystal (1.91 g) as cryogenic calorimeter exploiting a NTD temperature sensor. We observed an energy resolution of 3.9 keV (FWHM) at 238.6 keV, while the detection threshold is estimated to be 3.4 keV. Due to the presence of a permanent calibration source close to the detector, the reconstruction of the low-energy part of the spectrum was not trivial. For this reason, we set the analysis threshold to 80 keV, a factor of two lower than Ref. [16].

Table 1: Best fit results for the Interacting Shell Model on the parameters of interest g_A, sNME and $T_{1/2}$. The reduced chi-square χ^2_{red} is also reported as an estimator of the goodness of fit.

Model	g_A	sNME [fm^3]	$T_{1/2}/10^{14}$ [yr]	χ^2_{red}
ISM	$0.964^{+0.010}_{-0.006}$	$1.75^{+0.13}_{-0.08}$	5.26 ± 0.06	1.55

The enhanced SSM, combined with a low-threshold dataset, allowed to measure the energy spectrum of In-115 β-decay, its half-life and the corresponding free-parameters of the nuclear theory (g_A and sNME). We summarize in Tab. 1 the results of the best fit obtained within the Interacting Shell Model (ISM). The full results of the spectral shape analysis are reported in Ref. [21], while an interesting comparison with previous measurements of In-115 are detailed in Ref. [22]. Finally, the ACCESS data are also used as benchmark for nuclear calculations in Ref.[23].

Acknowledgments

This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie Grant Agreement No. 101029688 (ACCESS—Array of Cryogenic Calorimeters to Evaluate Spectral Shape).

References

[1] M. Agostini *et al.*, *Rev. Mod. Phys.* **95**, 025002 (2023)

[2] S. Abe *et al.*, *Phys. Rev. Lett.* **130**, 051801 (2023)

[3] M. Agostini *et al.*, *Phys. Rev. Lett.* **125** 252502 (2020)

[4] D.Q. Adams *et al.*, arXiv:2404.04453 (2024)

[5] O. Azzolini *et al.*, *Phys. Rev. Lett.* **129** 111801 (2022)

[6] C. Augier *et al.*, *Eur. Phys. J. C* **82**, 11(2022)

[7] F. Cappuzzello *et al.*, *Prog. Part. Nucl. Phys.* **128**, 103999 (2023)

[8] I. H. Hashim *et al.*, *Phys. Rev. C* **108**, 014618 (2023)

[9] P. Gimeno, L. Jokiniemi, J. Kotila, M. Ramalho, and J. Suhonen, *Universe* **9**, 270 (2023)

[10] J. Barea, J. Kotila, and F. Iachello, *Phys. Rev. C* **87**, 014315 (2013)

[11] C. Augier *et al.* (CUPID-Mo Collaboration), *Phys. Rev. Lett.* **131**, 162501 (2023)

[12] H. Ejiri, J. Suhonen, and K. Zuber, *Phys. Rep.* **797**, 1 (2019)

[13] P. Belli, R. Bernabei, N. Bukilic, F. Cappella, R. Cerulli *et al.*, *Phys. Rev. C* **76**, 064603 (2007)

[14] L. Bodenstein-Dresler and *et al.*, *Phys. Lett. B* **800**, 135092 (2020)

PoS(NOW2024)059

[15] M. Paulsen *et al.*, arXiv:2309.14014

[16] A. F. Leder *et al.*, *Phys. Rev. Lett.* **129**, 232502 (2022)

[17] M. Haaranen, P. C. Srivastava, and J. Suhonen, *Phys. Rev. C* **93**, 034308 (2016)

[18] A. Kumar, P. C. Srivastava, and J. Suhonen, *Eur. Phys. J. A* **57**, 225 (2021)

[19] L. Pagnanini *et al.* (ACCESS Collaboration), *Eur. Phys. J. Plus* **138**, 445 (2023)

[20] E. Celi, *et al.*, *Nucl. Instr. Meth. A* **1033**, 166682 (2022)

[21] L. Pagnanini *et al.*, *Phys. Rev. Lett.* **133**, 122501 (2024)

[22] J. Kostensalo *et al.*, *Phys. Rev. C* **110** (2024) 4, 045503

[23] G. De Gregorio *et al.*, *Phys. Rev. C* **110** (2024) 1, 014324